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THE FOLLOWING ARTICLES CONCERNING RESEARCH WITH THE VISUALLY HANDICAPPED ARE PRESENTED IN THIS BULLETIN--"TRENDS OF THE RESEARCH AND DEVELOPMENT PROCESS ON THE SENSORILY IMPAIRED--EUROPE AND THE U.S.A. 1966" BY M.D. GRAHAM AND L.L. CLARK, "THE PERCEPTION OF GRADIENT AND THE VERRING TENDENCY WHILE WALKING WITHOUT VISION" BY B.J. CRATTY, "VERRING TENDENCY AS A FUNCTION OF ANXIETY IN THE BLIND" BY J.C. HARRIS, "INFORMATIVE TACTILE STIMULI IN THE PERCEPTION OF DIRECTION" BY W. SCHIFF AND OTHERS, "THE GERMAN SYSTEM OF CONTRACTED BRAILLE--SOME CRITICAL POINTS OF VIEW" BY K. BRITZ, "AUTOMATIC TRANSLATION OF INKPRINT TO BRAILLE BY ELECTRONIC DATA PROCESSING SYSTEMS" BY H. WERNER AND OTHERS, "THE ABILITY STRUCTURE OF THE BLIND AND THE DEAF--FINAL REPORT" BY J. JUURMAA, "ELECTRONIC AIDS FOR BLIND PEOPLE" BY R.L. BEURLE, "USE OF TELEPHONE INTERVIEWS IN A LONGITUDINAL FERTILITY STUDY" BY L. COOMBS AND R. FREEDMAN, AND "SCREENING FOR VISUAL IMPAIRMENT" BY E. JOSEPHSON. BIBLIOGRAPHIES ARE INCLUDED FOR MOST OF THE REPORTS. THIS DOCUMENT IS AVAILABLE FROM THE AMERICAN FOUNDATION FOR THE BLIND, 15 WEST 16TH STREET, NEW YORK, NEW YORK 10011, FOR $1.50. (RS)

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PREFATORY NOTE

The *Research Bulletin* of the American Foundation for the Blind is intended to be a means of publication for some scientific papers which, for a variety of reasons, may not reach the members of the research community to whom they may prove most useful or helpful. Among these papers one may include theses and dissertations of students, reports from research projects which the Foundation has initiated or contracted for, and reports from other sources which, we feel, merit wider dissemination. Only a few of these find their way even into journals which do not circulate widely; others may never be published because of their length or because of lack of interest in their subject matter.

The *Research Bulletin* thus contains both papers written especially for us and papers previously published elsewhere. The principal focus may be psychological, sociological, technological, or demographic. The primary criterion for selection is that the subject matter should be of interest to researchers seeking information relevant to some aspect or problem of visual impairment; papers must also meet generally accepted standards of research competence.

Since these are the only standards for selection, the papers published here do not necessarily reflect the opinion of the Trustees and staff of the American Foundation for the Blind.

The editorial responsibility for the contents of the *Bulletin* rests with the International Research Information Service (IRIS) of the American Foundation for the Blind, an information dissemination program resulting from the cooperative sponsorship of the Foundation and certain scientific and service organizations in other countries. In the United States financial assistance is provided by the Vocational Rehabilitation Administration of the United States Department of Health, Education, and Welfare, and by certain private foundations.

Since our aim is to maximize the usefulness of this publication to the research community, we solicit materials from every scientific field, and we will welcome reactions to published articles.

M. Robert Barnett
Executive Director
American Foundation
for the Blind

CONTENTS

1 TRENDS OF THE RESEARCH AND DEVELOPMENT PROCESS ON THE SENSORILY IMPAIRED: EUROPE AND THE U.S.A. 1966. *Milton D. Graham, Leslie L. Clark*

31 THE PERCEPTION OF GRADIENT AND THE VEERING TENDENCY WHILE WALKING WITHOUT VISION. *Bryant J. Cratty*

53 VEERING TENDENCY AS A FUNCTION OF ANXIETY IN THE BLIND. *Janet C. Harris*

65 INFORMATIVE TACTILE STIMULI IN THE PERCEPTION OF DIRECTION. *William Schiff, Lane Kaufer, Sandra Mosak*

95 THE GERMAN SYSTEM OF CONTRACTED BRAILLE: SOME CRITICAL POINTS OF VIEW. *Karl Britz*

99 AUTOMATIC TRANSLATION OF INKPRINT TO BRAILLE BY ELECTRONIC DATA PROCESSING SYSTEMS. *Helmut Werner, Winfried Dost, Peter Seibt*

109 THE ABILITY STRUCTURE OF THE BLIND AND THE DEAF: FINAL REPORT. *Jyrki Juurmaa*

123 ELECTRONIC AIDS FOR BLIND PEOPLE. *R. L. Beurle*

133 USE OF TELEPHONE INTERVIEWS IN A LONGITUDINAL FERTILITY STUDY. *Lolagene Coombs, Ronald Freedman*

139 SCREENING FOR VISUAL IMPAIRMENT. *Eric Josephson*

TRENDS OF THE RESEARCH AND DEVELOPMENT PROCESS ON THE SENSORILY IMPAIRED: EUROPE AND THE U.S.A. 1966

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INTRODUCTION

Providing information to the scientific community concerned with sensory impairment is one of the major responsibilities of the Department of Research of the American Foundation for the Blind (AFB), principally through its International Research Information Service (IRIS). Relevant information is gathered in the usual ways: sampling a wide diversity of literature, visiting research facilities, conducting correspondence, commissioning papers, giving presentations, participating in conferences, and the like. Through the IRIS program (1),* such information is disseminated to some 500 recipients in 26 countries who have indicated their continued interest in receiving the IRIS materials. These materials may take several forms, such as periodic issues of the *Research Bulletin*, occasional bibliographies and monographs, and state-of-the-art reports (2).

This present paper might well be called a state-of-the-art report, for it incorporates the impressions and judgments of the authors (3) about trends of research and development (R & D) on sensory impairment and the behavioral effects of such impairment. We had occasion in 1964 to confer with our European colleagues for a ten-week period, after which we reported our impressions in a publication (4) restricted mainly to our respondents and some interested research workers. This year (1966) we were fortunate enough to be able to retrace our steps for a fifteen-week period, and to test at first hand our earlier impressions and judgments.

Over the past months and years we have been engaged in a dialogue involving scientists, research technicians, service-oriented workers for the blind and deaf-blind, and the severely visually impaired and the deaf-blind themselves (5). There is no doubt that that dialogue has become more meaningful to all concerned over the years. It is to encourage an even more meaningful exchange that we report our impressions in this paper.

Since our principal audience for this report is the research community, we propose to speak in their language in the hope that some further interaction of ideas and opinions on their part may be generated. In 1964 we reported that there was an inadequate appreciation of the R & D process, that necessary links in the chain were not provided, and that misleading products and ideas resulted. It seemed so fundamental that a useful chain must have equally strong links, that the whole R & D process must be honored, that in the light of experience we believe that we treated the topic too summarily. We seek to correct that seeming oversight by confining ourselves in this report to the sole topic of how the R & D process is honored or breached wherever scientists and research personnel purport to be concerned with science and/or with the welfare of persons with sensory deficits.

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* Notes and references will be found at the end of the text.

What then for purposes of this discussion do we consider the R & D process? We see a number of necessary steps, not always discrete, but certainly cumulative. We see as steps:

1. the posing of a problem to a mind trained in some aspect of scientific analysis,

2. the gradual evolution of an experimental or descriptive design to attack the problem,

3. the presentation of the design for support, financial or in kind,

4. the reporting of interim findings informally, and the presentation of a technically worded final report that incorporates corroborating data,

5. a developmental, or trial, stage that involves adequate training and a formal, controlled evaluation, and finally,

6. techniques for affecting practice.

This is the R & D process from start to finish as we see it and as we will discuss it in the report to follow.

COMMENTS ON THE RESEARCH AND DEVELOPMENT (R & D) PROCESS IN EUROPE AND THE U.S.A.

Step 1: Posing of the Problem

The initial step in the research and development process is a straightforward one. On one hand, there are problems acknowledged by all to be problems. On the other hand, there are disciplined and trained minds that by the nature of their training are curious and creative. The crux of the matter is to bring these together in a meaningful way, that is to say, to pose the problem properly so that the scientist becomes involved, *engagé* (in the fullest sense in which the French use the word). Our experience has been happiest when we pose the problems (or much more likely, interrelated problems) in terms that will rouse the scientist's curiosity. We have found that a vague, general approach like, "Wouldn't you like to help the poor blind?" has no impact, whereas a specific problem approach does have. To give an example: in a recent discussion with an internationally known acoustician at the Technical University in West Berlin, we mentioned our interest in obtaining information on the parameters of input data to the brain through two or more senses simultaneously, and explained the relevance of such data for research on the visually impaired. After a lengthy exchange he said that he had been considering collaboration with an ophthalmologist on the medical faculty to experiment with visual and acoustic input with an EEG readout; our assurance that such data would be useful and had not been collected elsewhere moved him to say that he would give the problem priority. He was, we felt on leaving, *engagé*. We felt that we had posed the problem properly to him.

Similarly, when we visited G. F. A. Harding, Senior Research Fellow in the College of Advanced Technology, Birmingham, England, we had a lively dialogue on his projected research project on the learning patterns of blind children as measured by intercorrelations of minimum auditory angle, IQ, school achievement, and behavioral measures. We mentioned some unresolved problems concerning uses of the EEG with blind children and promised to send ongoing research findings of others for his consideration in formulating his final research design.

Novikova of the RSFSR Academy of Sciences in Moscow assured us that her recently completed eight-year research project on sensory input to the brain was about to be published, and that some important gaps in knowledge would be filled by the book. It is worth noting that she spoke with pride about filling gaps in knowledge and that she believed Lairy, doing similar work at the Henri Rousselle Hospital in Paris, would corroborate her findings as well as making her own particular contribution to science.

We tell these somewhat personal stories (we have others we could tell) to illustrate our belief that the motivation of scientists is foremost to contribute to knowledge, and that if their creative energies can be used toward ultimate solutions of complex and perplexing problems caused by sensory deficits, we are all the better off.

The problems of sensory deficit, after all, will need the attention of many more devoted scientists before any partial or tentative solutions can be found. Indeed, we are pleased to report a growing general awareness among researchers in our field that much more basic research about the sensory processes needs to be done before our more specific or applied research projects can realize their true worth. As a colleague at the Massachusetts Institute of Technology (MIT) substantially reported at the St. Dunstan's International Conference on Sensory Devices for the Blind (to be mentioned several times throughout this report): "One day they brought me an engineering problem on a sensory device for the blind. It seemed fairly simple so I said I'd have the answer in two or three weeks. That was four years ago and now we have a team working on the possible answers!"

His response is typical of technologists and scientists who through their work have become aware of the complexity of problems to be solved in our field. At every specialized conference (such as the Rotterdam Mobility Research Conference and the San Francisco conference on research on children) the participants make it quite clear that there are no simple answers easily arrived at, and that long consistent effort and free flowing channels of communication among scientists and research technicians, particularly in the formative stages of research effort, are imperative if any useful findings are to be expected.

But if the scientists and research personnel are increasingly aware that sustained effort and free interchange of ideas are necessary, we see no corresponding awareness among *most* personnel engaged in service programs for the visually impaired. There is a general lack of understanding of the R & D process (as there always has been) and an impatience that it does not adhere to service and production schedules. There is very little allowance of the fact that R & D has its own rhythm and timing, that the questions posed must be in a special terminology, that creative minds cannot be scheduled like workshop production. It is this lack of understanding and intolerance of different ways of work that loses at the very beginning creative minds that might tackle the complex problems that confront us. If the scientist should survive this crucial first step of the R & D process, if the problems are posed to him so that he becomes *engagé*, there are other factors to be considered, as we propose to set forth in the discussion to follow.

Step 2: Evolution of the Research Design

Let us say that the scientist or technologist has become interested (perhaps "fascinated" is not too strong a word) with some problem or host of problems that relate directly or indirectly to the blind, visually impaired, or deaf-blind and how they might use their remaining senses better. Besides his curiosity, he brings with him training and experience. He must bring order to conjecture and speculation before attempting research. His first step may be to consult fellow specialists to determine priorities of problems, much as was done by the Union of Organizations for the Handicapped in the Netherlands convening an advisory group under G. Boiten of the Technische Hogeschool at Delft; after much consideration this group drew up a list of needed technical devices for the blind in order of greatest need and within their economic capabilities.

Another familiar technique the incipient researcher may use after consulting his own experience and the literature familiar to him is to call on, visit personally, other scientists and research personnel who might have some worthwhile ideas and suggestions. This can be a visit to a laboratory or research facility, or some time taken at a conference for a private meeting together; to be effective it is almost always a face-to-face encounter. In such situations insights that cannot yet be reduced to paper are given full play and this mutual face-to-face stimulation may cause a researcher to decide whether he proceeds with research or not, what course his research should take, and with whom in related research to keep in constant touch.

Personal interaction among scientists, technologists, and research personnel is so time-honored a device that it is seldom mentioned, yet in a field like ours where parameters are hazy or nonexistent, it can be crucial. We note with a great deal of satisfaction that within the last few years, face-to-face picking of brains has increased in our field, that specialists of widely varying disciplines have on may occasions sought each others' reactions on problems of the sensorily impaired. We think, for example, of Palmquist of the Institute of Applied Psychology of the University of Stockholm, touring research facilities in the U.S.A. and observing rehabilitation research techniques. Or more lenghy exposures such as the two years spent by Cohen of the Northwestern University Medical School (Chicago) at the Burden Neurological Institute in Bristol, England. We could name many more such visits and exchanges, as we will in illustration of other aspects of the R & D process later on. It suffices to say here that the amount of interaction among specialists in this formative state of evolving a research design has increased markedly in our field, so much so that the device of the whirlwind visit of two major conferences and some 30 institutions in three months (that your authors have recently gone through in Europe) no longer has the meaning that it had when researchers in our field were few and far between and largely unknown to each other. The small conference of specialists now seems to be a more efficient way of inducing interactions among scientific, technological, and research personnel.

Besides personal confrontation, the other time-honored devide for generating new ideas is the printed page, or to be more encompassing, the scientific information service. This was, of course, the main motive for creating IRIS of the AFB in New York and the International Information Center on Technical Aids of the International Society for the Rehabilitation of the Disabled in Stockholm.

In the case of IRIS, we started the *Research Bulletin* (13 issues have been published in three years) specifically to serve as an outlet for technical reports for the research community. It was intended to close the publications gap (reports often get printed two or more years after acceptance by many journals) and to bring together relevant articles from diverse fields (like articles from the *Journal of Diseases for Children*, the *Archives of Ophthalmology and Otolarangology*, and *Nature*).

Three years after its inception, our assessment is that we were naive to believe that a single journal could meet the need for information to the research community in our field. We found that we could not keep up with the number of reports worthy of being published and distributed in the first place. We found also that we were not transmitting through this single outlet information about on-going research that had not yet reached the stage of the written or formal report. Further, the number of special conferences that we could hold in any one year, and report of on-going research in the printed proceedings, was quite limited. Accordingly, we have agreed to try to include in subsequent *Research Bulletins* brief accounts submitted voluntarily to us of on-going projects - their aim, their main characteristics, and their principal investigator - so that individual researchers may contact the project staff if they wish. Whether this will close the information gap a bit more remains to be seen.

A third major drawback to anything like full coverage through the *Research Bulletin* has been translations, as we indicated previously in our 1964 report. In particular, we have had to exclude materials from our Russian colleagues because the cost of translating technical Russian into English is prohibitive. Consulation with our Russian colleagues has not resulted in any practical solution of the translation problem, either for them or for us. We think that our information service is the poorer for it.

With all its shortcomings, we believe that the reporting system of the IRIS serves its basic purpose of providing relevant and provocative information to researchers, particularly those who are in isolated areas where face-to-face interaction is not often possible. In this connection, for example, we found that our colleagues in Finland (Juurmaa at the Institute for Occupational Health, Helsinki, and Weckroth at the University of Tampere) were grateful for IRIS services whatever the shortcomings in stimulating new ideas and challenging old ones might be.

In the formative stage of examining possible ideas and concepts that will contribute to a formal research design, the researcher makes use of all sources of concepts and data, written or spoken. Then he "freezes" a tentative research design, a formal statement of aims and procedure that may be reformulated as the research progresses (such as Youtz at Barnard College, New York, has done after his initial work on aphotic digital sensing).

In summary, the conscientious researcher uses all sources available to him in formulating his research design, and the more material available to him the more meaningful his research is likely to become. If there is any one point at which it becomes relevant to say that science is *international* it is at this point in the R & D process, when every idea, every bit of data, from whatever source or place, is weighted in the balance before the formal research design is worked out.

Step 3: The Obtaining of Support

Once the scientist, technologist, or research technician has come up with a viable research plan, he faces the necessity of obtaining support to carry out the work. This support may be in cash or in kind; it may be for a short period and renewable on reapplication or it may be long-term; it may be from one or multiple sources. Whatever its character, it is the lucky research worker, indeed, who does not get entangled in administrative interpretations of laws, regulations, and traditional practices that await him unless he is wary. Since all research in a sense involves the disbursement of *risk* capital, it is understandable that some financial safeguards are necessary, but the extent to which they are sometimes carried can only be called absurd and self-defeating.

The fortunate researcher arranges with his peers the necessary facilities, manpower, and perhaps funds in an academic or research setting. The work of Linvill at Stanford University (Palo Alto, California) and of Winkel at the Technical University of West Berlin are examples of this kind of support. It has the advantage of coming from peers who understand the R & D process, if not necessarily the specific problem.

If the researcher must seek outside funds (and most do these days since research is expensive) he can run the gamut of administrative and bureaucratic processes with unpredictable success. Probably private organizations offer the most friendly ear. For example, St. Dunstan's, an organization devoted to the welfare of the British war blind, has sponsored extensive technological and psychological research on mobility devices; it seems to us that organizations for the war blind in other countries might well follow this lead as the numbers of the war blind needing help dwindle. Then there is the example of an American "family" foundation built on an oil fortune giving an unrestricted grant for a study of leisure time activities of blind adults; it happened that one of the family was blind. In Sweden, a wealthy man regaining his eyesight by surgery contributed substantial funds to a rehabilitation research program. These are examples of funds from private sources that the researcher seeking funds may find more hospitable, but unfortunately their number is few.

Other private sources of funds, also relatively modest in number, are commercial or industrial concerns. An example is the Xerox Corporation giving Youtz of Barnard College (New York) funds to undertake exploratory research on tactual recognition. In Norway, the Institute for Industrial Research undertook research on reading machines with contributions from industry; unfortunately this has been discontinued. the International Business Machines Corporation (IBM) has both sponsored research and provided equipment, as for the American Printing House for the Blind (APH) in the automatic braille production program. IBM has also made contributions to a similar program in West Germany at the University of Munster.

These are examples of positive sponsorship of R & D. We could repeat our statement from our 1964 report that some negative practices exist among some commercial or industrial sponsors of research involving the short-cutting of the R & D process, like putting a device into production before adequate evaluations (and possible redesign) of it are made. The tendency to exert proprietary rights so as to exclude competition still occasionally comes to our attention. Generally, however, large commercial and industrial concerns who are acquainted with the R & D process are sympathetic to the risk-taking nature of R & D, and particularly so for something so complex as the effects of sensory deprivation.

Not so the government agencies which, unfortunately for the researcher naive to bureaucratic ways, sponsor the great majority of research done. They too often consider knowledge of the R & D process unnecessary in their zealous pursuit of protecting public funds. In the U.S.A. at least, so-called lay members (that is persons proud of their knowledge of "practical" ways of doing things) are prominently represented on the fund-giving councils; other members are specialists who may or may not have any knowledge of sensory deprivation, most likely not. One council which dispenses several million dollars annually to research on visual impairment has had no one qualified in that field on the council for two years. These groups often reject a research proposal as "not within their purview." An internationally known clinic once applied for research funds to study therapeutic techniques for handling severely emotionally disturbed blind children. One institute of the U.S. National Institutes of Health rejected it as a mental health project, the other rejected it as a blind project, and only after a year and a half was a combined token grant made. But if these jurisdictional disputes are understandable (and we see no reason why they should be), it is beyond the realm of comprehension to excuse the bureau of the Public Health Service that changed its application forms three times in one year, each time requiring resubmission on the new forms; one proposal on the social life of a sample of blind adults was thus delayed about two years before it was finally rejected as "not in our purview."

We could give more examples of bureaucratic pettifoggery that discourage R & D efforts in the U.S.A., but we know that they exist practically everywhere else. In France, for example, the researcher wishing to obtain government funds for a project involving the limitations of the EEG as a diagnostic tool for examining blind children must secure the approval of *three* ministries; if by some remote chance these three ministries agree, then the delegate from the Ministry of Finance most likely objects, and the months of effort are lost. (This is not an apocryphal story.)

Lay members, specialists of irrelevant specialities on councils, and negative delegates from the finance ministries notwithstanding, the grant-making machinery might work somewhat more to the advantage of the researcher if long-term grants were the rule instead of the exception. Take the example of basic research projects (and we will stress throughout this report that a great deal more basic research on the sensory processes is imperative if we are to know what it means to be deprived of those senses). Basic research requires long spans of time and effort, not year-to-year progress reports made for the disbursers of funds. We can do no better than to quote this warning in an editorial entitled "Basic Research in Peril" from the *New York Times* of 12 August 1966, which said in part,

> "It is understandable that politicians want quick results, preferably in time to provide useful material to be included in campaign speeches before the next election. But scientific progress has its own laws and its own tempos and it would be perilous for the nation to ignore them.
>
> "Basic research provides the capital fund of scientific knowledge on which applied researchers draw to give society a rich rate of interest. But if that capital fund is not expanded or is increased too slowly, the time will come when applied research too will be frustrated for lack of fundamental new ideas and new knowledge."

If basic research cannot thrive when it is at the mercy of a time-clock mentality, neither can applied research. Consider a negative example. We have it firsthand from a well-known specialist on manpower training systems that on submitting a research proposal to a U.S. governmental agency, an administrative employee told him his proposal would be better received if he were to omit certain sections. He complied and received two one-year grants in succession (it was a proposal for a five-year program), but was rejected on the third year because certain considerations were missing from the proposal. They were, of course, the points that he had taken out at the insistence of the administrative employee. This proposer never returned to the agency for further "advice."

We tell this chilling anecdote to illustrate our belief that at no point in the R & D process is its success more in peril than in the funding and refunding stages. If we are largely negative on this point, we believe it is because we have reason. We know also that there are conspicuous examples of government support providing a minimum of administrative and bureaucratic hinderance. There is the basic research on obstacle detection at the Stanford Research Institute, now in its third of five years, and supported by one of the National Institutes of Health. Another example is the eight-year project on brain research involving blind children (just completed and to be published in 1966) of Novikova of the RSFSR Academy of Sciences. We are happy to note these positive examples of governmental sponsorship of research and we hope that they can be attributed to some knowledge of the R & D process on the part of the sponsoring agencies. We note with some pleasure preliminary plans establishing a research center with governmental and other support at Peabody College (Nashville, Tennessee) in cooperation with the American Printing House for the Blind (Louisville, Kentucky). If this multiply-funded program of long-range research on educational problems clears the early financial and administrative hurdles it may well set a model for R & D efforts in the field in the U.S.A.

From this part of the process, we would like to proceed directly to the matter of reporting research, assuming that the researcher has gotten his financial support, is skilled in undertaking the research, and now has completed some integral part of his original plan, or enough of it at least to warrant a report of his progress.

Step 4: The Reporting of Research Findings

The dissemination of research results is, if our view of science is correct, equal in importance to the work itself. If science is public knowledge, then only by distributing the products of scientific work widely can one make possible the examination of basic hypotheses and the reformulation of hypotheses we referred to above. The difficulties of dissemination, however, quite aside from the initial one of commiting one's work to paper, are so manifold that an air of mystique has grown up around the process in the view of those outside the research community. Much time and effort has been devoted to the problem of the most efficient organization and dissemination of research results in part because of the fecundity of the scientific method, and in part because in the face of this fecundity there is always too little time and too few personnel to deal with the endless stream of knowledge flowing from laboratories and research institutes.

Even in the field of sensory research, and in the application of research results in the narrower field of blindness, deaf-blindness, and severe visual impairment, the growth of research activity during the last five years rivals that of the preceding twenty-five; and we seek constantly new ways of dealing with the enormous extent and depth of our interests. Surely the time is coming when it will be uneconomical, in terms of overall effectiveness, to present even a cursory examination like the present document. We cannot hope to present more than highlights of two- or three-month visits every two years combined with highlights of other shorter visits.

Yet each of the methods utilized to disseminate research results (i.e., technical reports not abstracts or popularizations of scientific work) has to do with "keeping in touch." The increaseing speed and increasing sophistication of research places ever increasing demands on us for current information and current data useful here and now, and in the work undertaken by researchers hundreds, even thousands, of miles apart. Only a little less demanding is the need for written records of completed phases of work done so that hypotheses can be formulated and refined in retrospect. In general, it can be said that as contact between researchers becomes more and more face-to-face the need becomes progressively greater for current and detailed data on work currently under way. On this criterion we can rank the means of reporting of data and exchange of views currently practised along a dimension of the directness of personal contact involved.

Personal Visits Among Researchers

Possibly the most effective exchange of data and views occurs when one researcher actually goes to the laboratory or institute of another and spends a period of time there working or observing. In our field there are several examples to draw upon. Thus Werner of the University of Munster took the opportunity, when he was oppointed to a one-year lectureship at the University of Southern California, to interrupt his travel itinerary from Germany to California and visit the MIT Sensory Aids Group, the IRIS in New York, and the APH in Louisville, Kentucky, all of whom were involved with the problem of computer processing of ink print coding to braille coding in automatic transcription of braille. These visits were all the more important at that time (1963-1964) because there were few written details available on the specific nature of the computer program worked out jointly by IBM and APH. Quite possibly these visits saved years of duplicate effort in creating a similar program in the German Federal Republic.

Another celebrated example of personal visits is that mentioned earlier of the two-year long stay of Cohen at Grey Walter's laboratory at the Burden Neurological Institute in Bristol, England. The prolonged exchange of views and data has resulted not only in a summary article of the investigation of the interpretation of the EEG in the case of blind children, but also in a book to be published shortly (6).

Again, in a somewhat more problem-oriented context, we can cite the visit of Nielson of the Danish Association of the Blind to Sobov (Professor in Mathematical Machines) and Sverlov (Professor of Logistics) in Leningrad University, RSFSR, in 1965. Nielson discussed the application of teaching machines to the education of the blind and deaf-blind, and discovered a dissertation on the subject just completed by Alekseev. He made similar visits to the Royal National Institute for the Blind in London to discuss several matters, including the automatic production of braille.

Let us reemphasize that we have quoted only a few of many available examples. The importance of direct visits lies in their economy of exchange of views and data regarding specific areas of interest for the visitor and his host. A potential danger inheres in this method only because it is essentially, and necessarily, a selfish exchange. Unless such visits become far more frequent they do not promote the interests of large scale international efforts of cooperative undertaking, although they ease the flow of information toward that end. For the specific tasks of individual researchers engaged in a common enterprise, the world has not discovered a better method of exchange.

Reports at Conferences

When the volume of work in a specific field warrants it, the exchange of data at conferences organized around the content of researchers' interests may ease the burden of visits of individuals to laboratories and research institutes. This is especially so when a field of work has been defined through individual efforts and a resultant body of data has grown up; that work then requires examination vis-a-vis a related larger body of knowledge. This can be done every two or three years through the calling together of a small specialized conference. Such conferences may include the practitioner of services (the worker for the blind) who can interact with researchers. Through their exchange, but within the context always of the scientific process, a dialogue is begun between researcher and practitioner in which the researcher might be able to reformulate the problems of the practitioner in a way meaningful to both of them. During this interaction the researcher learns to take into some account the day-to-day realities which are forced upon the practitioner. The result of this dialogue, if it is successful, is the creation of a common core of meaning, a community of language, and a sharpening of thought regarding problems shared by them. Such conferences, then, can serve the dual purpose of conserving the time and energy of researchers who have common interests by easing the burden of travel; they also promote a useful exchange of basic knowledge about the human being with sensory impairments and the social and physical environment in which he operates.

Such is the theory of the conference. What is surprising, perhaps, is how well it works out in practice. At both the 1964 Rotterdam conference on mobility research, which we aided as organizers (7), and at the 1966 international conference on sensory devices for the blind sponsored by St. Dunstan's in London, in which we were participants (8), we were struck by the degree to which this essential dialogue between researcher and practitioner seems to improve with practice. Some researchers (as for example Mann of MIT), indeed have learned to function almost as well in the area of practice as they do in their own bailiwick.

No one will claim that learning to participate in this dialogue is easy, but hardly anyone will deny that it is, after all, both essential and rewarding. One cannot know the limitations and reservations a researcher may have about his product unless one sees it in its potential context of use. This is particularly easy to see in the case of technological products like mobility devices. At the same time it becomes obvious that one cannot dismiss an eary prototype of a device because it does not solve all the mobility problems, of all blind persons, everywhere. It would seem that the researcher's argument for a multiplicity of solutions to the problems of mobility has gained a wider and more sympathetic audience among practitioners, who appear now to welcome the prospect of, for example, a wide variety of mobility devices or reading machines, taking into account not only the needs, but also the personality of the potential user. The consequences of this dialogue can barely be imagined, for it is evident that as we learn more about the capabilities of the human being to absorb information from instrumentation designed to overcome the impedance of the man-machine interface we shall arrive at still better and clearer ideas of what instrumentation is wanted and necessary.

The conference, therefore, fulfills a dual purpose. On the one hand it provides a compact and economical vehicle for the direct interaction of researchers with one another, partly through the presentation of papers, more importantly through the many opportunities offered for personal contact in a stimulating crosscurrent of ideas. On the other hand, it provides a formal context of rational exchange between two universes of discourse, that of the researcher and that of the practitioner, which might never otherwise be so comprehensively explored.

Written Reports Covering a Span of Time

A report of a bloc of activities, carried out over time, and written in the richness of context and experience gathered by a researcher, has the disadvantage of an address to an audience who cannot respond directly, and the additional disadvantage that it must be out of data when it appears (because of the publishing gap that we alluded to earlier). This latter shortcoming is shared by all published materials, but an annual report may have the advantage of providing the reader with a description of the institutional and instrumental and staff setting within which a technical report becomes most meaningful. We are thinking here of reports such as that Dupress wrote on the multiple activities of the first year of full operation of the Center for Evaluation and Development of Sensory Aids at MIT (9); and of the series of remarkable annual reports of research undertaken by Nolan and his associates in the Department of Research of the APH on questions concerning braille coding and braille learning (10).

Such reports are invaluable because they stress the continuities of research in institutional settings. For one's colleagues in the research community, whom he will meet personally at some time, they provide a meaningful framework to discuss mutual interests in work. Only by knowing this context, indeed, can one speak about the possibilities of cooperation and of sharing the investigative burden, even on problems narrowly defined. As a record of work already done, such reports serve as an introduction to the primary assumptions and implied directions of a researcher, and indicate his shared points of view with colleagues.

Written Reports Covering Specific Technical Data

We have just spoken of reports in which a series of conclusions may be brought forward to summarize a series of studies over time. Yet there is often a barely perceptible difference between these and reports which deal with a specific subject content. These, too, may summarize work done over a span of time, and of course they name and specify the place in which work was done, the sampling procedure, the data collection procedure, and the implications to be drawn from the data. Their primary purpose, however, is not to convey a description of how a group of researchers distributed their energies over time; rather their purpose is to transmit data. Long-term effects usually result in a report which summarizes data collected over a period of time by one or more research teams. As examples of this kind of report, we can mention Nye's description of reading machine research at the National Physical Laboratory in Tedding, England (11); Juurmaa's report on the ability structure of the blind, done at the Institute of Occupational Health in Helsinki (12); the doctoral dissertation by Imamura on the interaction of mothers and their blind children from the point of view of comparative anthropology (13); and many others (14).

Unpublished Written Reports

These are perhaps some of the most fragile and unpredictable sources of information we have, for if they are not assiduously searched for and made available by whatever means, they may be lost to the researcher. In publishing them in the *Research Bulletin* we can only help to bring them to the attention of the research community; we also try to include mention of them in the bibliographies published by the IRIS. We are thinking here of such valuable sources of information as Liddle's doctoral dissertation on the parameters of the haptic sense, and Alekseev's on the use of programmed texts for teaching the blind in school (15, 16).

It is important to realize that however disparate these several elements in the chain of information flow may appear, they form an organic continuity without which the research process, as we see it, cannot operate. Our presumed hierachy along the dimension of directness of personal contact seems to give a programmatic outline of the course of an hypothesis: through its formulation in an internal document, then in a technical report of an experiment or incorporation into an annual report, then more formally in a paper at a conference, and finally as an item treated in direct intercourse between researchers. We said above that science is public knowledge, and in this sense the reporting of research findings constitutes one of the most fundmental activities of the researcher, no matter how bothersome or how painful he may find the need to write. The free exchange of data and views is an essential part of the research process, and to the extent the freedom of information flow is impeded for any reason whatever, to that extent the research process is hobbled and defeated and its benefits lost to the scientific community.

Nor should we become complacement about the effectiveness of the appeal for the dialogue between researcher and practitioner we referred to. Progress in extending the dialogue is slow, for it involves the practitioner and the researcher in learning a new language of discourse. If it is successful the practitioner cannot expect quick and ready answers to his immediate problems in terms he can immediately translate into his daily work; we cannot expect ingrained and habitual patterns of work to change so readily. Furthermore, we must also say that so far only a few pracitioners have learned these hard truths. All too often the practitioner is impatient with his scientific colleagues who may require a fundamental examination of his habits and experiences for which he had not bargained in his request for assistance or ideas; generally the desire is to be reassured, not reexamined. We have known many researchers, not understanding this, whose keen interest in the problems of the sensorily impaired has been lost to us as a result. We offer no ready solutions to this very human problem of misunderstanding; but so long as dialogue continues between researcher and practitioner, there is hope.

Step 5: Development, Training, and Evaluation

Perhaps a few words to the reader may be useful to explain our inclusion of development along with the additional factors of training in the use of prototype product and the evaluation of that product's effectiveness. Certainly the incorporation of training into this phase in an explicit sense represents a new awareness of its importance to researchers, as we shall point out below (although we mentioned training explicitly in our 1964 report as an essential component of the full R & D process). Now that the importance of training in the use of a product before evaluation has become much clearer, we should also like to point out that training plays an equally important role in the adoption of techniques or ways of handling the products of research whether they are technological or psychosocial in nature. We shall not greatly elaborate this point in what follows, for it is far easier to show what is involved in evaluating tangible products like mobility aids and reading machines. In assessing the usefulness of a measure of tactile sensitivity (17) in educational research, it is essential to train the subject in the tasks required of them before comparison with more traditional or existing procedures can be used. It can on no account be assumed that such training is "built-in" and that well-prepared and well-controlled training programs are unnecessary. Many scientists, technologists, and research technicians, to their dismay, have learned this too late.

To the present community of researchers in our special field, the importance of training before evaluation has become very obvious in the development of the mobility aid developed by Kay, and made on a regular production line by Ultra Electronics, Ltd. in the U.K. A great deal has been said and written about this device; it has become obvious that one cannot answer simply the question "Is it good?" without asking in response, "Good for what?" It is known that the output of the device (the audible signal feed to the earpiece) is rich enough and complex enough that it can be utilized in a great many different ways; so many, in fact, that it was suggested at the 1966 St. Dunstan's conference in London that the Kay device be called an "environmental sensing device," rather than a mobility aid (the latter is presumably a more restricted class included in the former). Gissoni's paper in a recent journal article provides an illustration of what we intend by the term "complexity" to describe the output of the aid (18).

Investigation and training with this device have shown us, indeed, as in the reports given at the St. Dunstan's meetings, that to use the device with anything approaching a suitable level of competence as a mobility aid, one must have highly motivated students, of better than average intelligence, who are fairly young, and willing to undergo more than 100 hours of training at a minimum. In addition, there is an important personality variable involved: they must have good tolerance for ambiguity. With so many factors affecting performance, it is easy to see why evaluation of any device such as the Kay aid becomes not only a difficult and demanding process, but one which unquestionably must be done by highly skilled investigators, under carefully controlled conditions, and with full awareness of the implications of the findings for further modifications. It may even appear that we must revise the training schedule in the light of these new facts before an adequate evaluation can be made.

So far we have available two full scale evaluations of mobility aids, both done in the U.S.A. under auspices of the Veterans Administration: one by Deatherage of TRACOR, Inc., Austin, Texas, of the Benham pulsed transmission obstacle detector; the other the evaluation of the Kay aid, whose results have been mentioned above, by Riley and his co-workers at St. Pauls Rehabilitation Center, Newton, Massachusetts (19, 20). We find it interesting that both investigators found evidence indicating crucial personality variables as factors in success with an aid to navigation, factors foreshadowed by Mann's plea in 1962 for a wide variety of devices available to the handicapped which would allow selection of a prosthesis by need and temperament of the user (21).

The Kay aid is also being evaluated at the National Physical Laboratories in the U.K. (22), and at the Center for Sensory Aids Evaluation and Development in Cambridge, Massachusetts. With these, and the addition of a few isolated cases of evaluation of the Kay aid on a small scale (like that of Juurmaa in Helsinki), we come to the end of known efforts at properly controlled evaluation.

Perhaps it is of some consolation to realize that these are developments antedating the 1964 Rotterdam mobility research conference, and to note that now there is a much keener realization of the need for training in the use of a device before it can be evaluated meaningfully. It has also become clear, in the investigation by Bliss of the potentialities of data transmission through the tactile sense (23) and that of Youtz of the appreciation of tactile patterns of embossed characters (24), that not only is training necessary for proper evaluation, but we may indeed have seriously underestimated the power and discrimination of the sense of touch. Such investigations clarify one of the essential features of the research process, for if proper evaluation had not been carried out these researchers would not have been led to new and fruitful studies of the limits of the haptic sense.

Evaluations may also serve an additional important function, that of redesign of a device. The evaluation of the Kay device has benefited from this flexibility in the stages leading up to the present product; similarly, the Deatherage evaluation of the Benham device has led to new considerations on the design of both obstacle and curb detectors. Evaluations in use of the RNIB tape cassette talking book machine have led to further refinement of the entire system, resulting in a compact reproducer with a much smaller cassette of high reliability, and a copying system which allows operating economies of one-third less than the original system; the Soviet tape system is undergoing similar transformations.

Finally, we can cite one striking example of evaluation of a technique, the RNIB examination of the practicability of the "long cane" technique under British conditions. Although at less than the purely formal level of the evaluations mentioned already, a careful comparison of travel behavior of persons using this technique with other travel techniques has encouraged the scheduling of an extended trial of training with it.

Evaluations properly conducted under controlled and publicly specified conditions by competent investigators are hard to do, take time and money, and by no means guarantee a happy outcome. Yet in every industry and in every field of scientific activity they are an accepted part of the R & D process. We can expect no less of sensory aid research and development if we want to produce viable goods and techniques to overcome sensory deficits. We are at least at the stage where it is becoming more generally recognized that this is so. Two years ago we could not have said this much. There is hope that this trend, if a trend is indeed indicated, will allow us to say much more encouraging things about evaluation in the next few years.

Step 6: The Application to Practice

To put into practice the findings of the process of research and development should be, in theory, the easiest part of the research process. In actual fact it is often one of the most difficult. To be sure, the research process can provide the answers to fill in missing gaps in knowledge, and can evaluate the effectiveness of a device or technique. There are still many obstacles before this theoretical level of effectiveness can be realized in practice. No doubt there are many factors involved in this unhappy situation, but one seems to stand out above all others: the dearth of personnel who combine administrative skill with an understanding of the product, and an organization of their talents to put the product into use. And one other obstacle: the distrust (sometimes fear) of change that, even when a new and alternative solution to a problem is offered, cause those who first asked for change to be overly cautious, unsure of their ability to apply it and to utilize it. As we mentioned before, practitioners often ask researchers for reassurance not innovation.

In a few rather striking instances, however, we can point to examples of successful application in practice of solutions to problems derived through the research process. In the area of devices, for example, some organizations have undertaken the difficult task of taking a prototype model, adapting it to a production model, then arranging for production, overseeing quality control procedures, distributing the product, and providing repair service in the field. The British tape talking book system was introduced in this way; so was the insulin syringe the Dutch developed for blind diabetics; so was the Typhlocane or Hoover cane the U. S. Veterans Administration developed for blinded veterans. The organization and administration to carry this application out have gone further, perhaps, among the Dutch than any other people. Besides the priority listing of items desired for the impaired (indicated in a previous section), one central organization for the handicapped administers the entire R & D process as we have outlined it here. It will be most interesting to watch their work as they tackle ever more complicated research products.

Psychosocial research findings have been applied to practice by influencing social policy and legislative activity. The comprehensive five-year study of the handicapped carried out by the Danish National Institute of Social Research, for example, was used to draft enabling legislation for programs of social welfare, the most comprehensive example of such application we have seen (25). In a similar though more modest way, the retrospective study of McPhee of rehabilitants in Wyoming was offered as evidence to the state legislature and substantially aided the passing of bills for additional funds for rehabilitation services (26). As we pointed out in our 1964 report, the Academy of Pedagogical Sciences of the RSFSR is responsible for educational research on curriculum and teaching techniques, the products of which are used to set standards for the whole of the USSR.

Recently, we were told, additional experimental schools are being established in the USSR to explore new methods of teaching the blind, the mentally retarded, the multiply handicapped, and the partially slighted, and it is expected that similar standards will issue from the special studies conducted there. On a more general level, finally, one of us (Graham) has pointed out in a paper presented to the 18th International Congress of Psychology in Moscow of this year that emphasis has shifted in recent years from a concentration on the *limitations* of the handicapped to a new concentration on their capabilities and potentialities (27). Research (medical, technological, and psychosocial) can be given a great deal of credit for this trend.

It should be stressed again that the responsibility for application to practice does not end with the provision of a product or service to the handicapped user. The essential nature of the research and development process includes many feedback loops to maintain a dynamic equilibrium. One of those loops links the experience of users in the field with the administration responsible for applying the product of research; another links users' experience with the evaluative stage of the process. In this way some account can be taken of the operation of factors in real life situations not adequately accounted for in the earlier stages. The Dutch organization already mentioned attempts to include this function in its administrative set-up. Another and ingenious solution to part of this problem is afforded by the example of the British National Research Development Corporation (NRDC), set up under the Ministry of Technology of the U.K. The NRDC, in effect, is responsible for awarding sums of money regarded as "risk capital" to support production and to evaluate production prototype of devices. Their deliberations before awards are thorough and of high professional caliber, and their interest follows the product through to the user. The organization is new, having been set up only three years ago, and it will be interesting to see how this experiment in fully independent evaluation of research products carried through to the user will work out over the next few years.

It would certainly be amiss not to point out also that long records of experience can serve as an alternative method of rational planning in carrying out application to practice. We shall soon have in hand the record of some 15 years of administering a nationwide program of vocational rehabilitation of the blind in the USSR. Hopefully, in about a year from now, Yazvina and a team of four co-authors from the All-Russian Society for the Blind, will set down their experience of the last decade and a half. Since the association is now responsible for a 330 million dollar industrial organization employing both blind and sighted workers, they are possibly the world's most experienced vocational rehabilitation specialists, and we look forward to their book with keen interest; it will almost certainly be a material contribution to the field of vocational rehabilitation.

THE PROSPECTS FOR CHANGE THROUGH THE R & D PROCESS

We have presented in the foregoing sections our view of the R & D process, its essential steps, how it can be honored in the observance and ignored and dishonored in the breach. Certainly, as a method, it appears to us superior to any other for generating knowledge which can then be systematically applied in the service of man. Its greatest value is in the conservation of the talents and energy of gifted people in applying themselves to the solution of some of the oldest scourges of humanity. But hardly less important are the serendipities in the new avenues of exploration open to us. The process we have described is not only self-correcting, but also self-regenerative, for no solution is final, and improvements and extensions always are possible.

What then of the foreseeable future? What can we expect as proximate goals in the next few years arising out of the process we have described? Let us consider some possibilities based on current work.

First, we can expect further confirmation of the limitations in standard practice of EEG evaluation of blind children. Novikova has developed diagnostic techniques for differentiating not only the blind child from the mentally retarded child (types often confused in present practice with tragic results) but will also distinguish the record of blind from blind/mentally retarded children. It is likely that there will be even further corroboration of these fundamental confusions in EEG diagnosis first revealed by a group which included Lairy (Paris), Grey Walter (U.K.), and Cohen (U.S.) (28). We can also expect further advances toward a general model of the mechanisms and processes by which the brain processes visual, auditory, and tactile signals. We shall say a bit more about this last below.

From the basic studies now under way on braille by Lowenfeld and Foulke (29, 30) we may expect further additions to our knowledge of the optimum methods of teaching braille to children, and of the possibilities for change in the braille code itself for a variety of purposes (making it easier to learn, more useful for machine processing, and the like).

The studies of the sense of touch, using tactile and electrical stimuli, will add extremely important information about this sense to our meager repertory of knowledge of how the human receives information from the world about him. This basic knowledge will find immediate application - to the specification of plastic to supplement paper technology in producing braille, to possible refinement of braille cell dot spacing specifications, to the design of tactile displays in general, and thus to the man/machine interface of mobility aids and reading machines using a tactile output (31). Such studies are now under way by Bliss and Linvill at Stanford (32), Gibson in Pittsburgh (33), and Boiten in Delft (34).

Mobility machine research may well take added impetus from the dual channel binaural ultrasonic devices by Kay in New Zealand and Laan of Lockheed Aircraft Corporation in Santa Monica; and from the proposed head-mounted device of Bliss at Stanford (35, 36). The studies by Cratty and others on the veering tendency lends added validity to the proposition that one avoids the problems of multiple autocorrelations of kinesthetic and auditory (or tactile) signals best by avoiding the phase differences involved in hand- or chest-mounted mobility aids (37). We are also likely to see a range of mobility devices become available with which we can hope to match the particular needs and personality structure of the user with a device to ease his travel.

With reading machine research, we see the eventual availability of devices to supplement braille and the talking book. Some of these, like the Battelle and Mauch Laboratories devices, will be best adapted to a personal reading aid for use over short periods of time (38). Others, like the ambitious and sophisticated Haskins Laboratories device, will be located in libraries where, by recording their spoken (and spelled-word) output on magnetic tape, they will provide a tireless supplement to the recording of library tapes (39). We do not feel that it is likely that there is a very bright future for devices using additional artificial languages unless some rather different kinds of easily assimilated codes become developed.

In the allied area of braille research we foresee exciting possibilities for the extensive development of nationwide telecommunications links to support the now fully feasible automatic production of braille books. Technologically the problem of producing books simultaneously in ink print and in braille is solved; what remains is the enormous organizational and administrative task of implementing the technology we have developed (40). Recent advances in computer technology which permit graphic display also give us reason to hope that the remaining fraction of books still done by human beings for braille users (in mathematics and music, for example), can also be significantly reduced.

One useful side effect of the work done to create braille transcribing programs for the computer was to focus attention on the braille code itself. At least two consequences followed. One was the opening of possibilities for extensive study of the efficiency of braille as a code, using the computer as a computational aid (41). The other has been to accelerate the process of agreeing on standardization of simplified and rational coding schemes for braille in Europe, where automatic braille transcription will become a reality early next year (1967) for the first time. If a concurrent development in plastic technology permits still further reductions in the cost of stock on which braille is printed (the paper accounting for the greatest per page cost of automatically transcribed braille by machine) there is no reason why "old" and "new" braille codes could not be produced to order to suit the conflicting needs of relatively small groups of readers. The possibilities of simplifications of braille coding are an interesting prospect to consider, also, from the pedagogic point of view and from the standpoint of the market for braille.

We have mentioned pedagogy, and there is much to be expected from the revolution which is beginning to follow the recent marriage of technology to education. The dissertation by Alekseev at Leningrad gives some idea of this application to our field, as does the modification of the operant conditioning teaching machine to the special needs of blind and deaf-blind students (16, 42). New and ingenious uses of tactual graphics are suggested also by the work of Leonard on map making, and the project at the Worcester

School by Pickles on new displays (both in the U.K.) (43, 44).

In the area of vocational rehabilitation there is still a vast and virtually uncharted region for good research and development programs which will eventuate in program and policy changes. We look forward to the book by Yazvina mentioned above to initiate serious interest in carefully conducted, independent, longitudinal studies of rehabilitation effectiveness scaled to the expressed needs of specialists in the field. This seems to imply the participation of pyschologists in the comprehensive development of tests and measurement instruments to aid in this kind of evaluation. We note with pleasure the appearance of one of the too infrequent scientifically conducted surveys like Dishart's on characteristics of rehabilitation clients and counselors (45), and we hope that similarly conducted retrospective studies of rehabilitants will offer us some scientific (as opposed to idiosyncratic) insight into the rehabilitation process. We found nothing in Europe nor the U.S.A. to satisfy us on this score.

Finally, we should like to mention the possibility of development of models for the creative use of leisure, to match the considerable effort already expended to make possible the creative use of vocation in the life of the sensorily impaired. The studies by Josephson of leisure time use by the blind, the study of Graham, et al. of a selected group of war-blind veterans, and our paper presented to the St. Dunstan's conference, all point toward the creative use of leisure as a problem worth tackling (46, 47, 48). In a society in which increasing specialization and increasing automation make possible both a high standard of living and an ever-shortening work day, we face the problem for the sighted as well as the blind of planning toward the creative use of leisure time and the broadening of professional training programs as in days passed we faced the problem of creative use of work time. As we see it, the field of work for the blind, which spearheaded many innovations in social life of the sighted by insisting on social legislation for the handicapped, by introducing the long playing record (33-1/3 rpm), and by other innovations, faces a new challenge to create a model for society in the measures the field proposes for the use of leisure by the impaired.

From one point of view, our meaning is well expressed by what the Europeans intend by the term "rehabilitation." We can do no better than to quote once again the Danish statement which appeared in our 1964 report:

> "The concept of rehabilitation is not confined to a series of measures of techniques aiming at the normalization of the occupational situation of physically and mentally handicapped persons. Rehabilitation is thought of as an objective which should to a large extent influence the general

> social policy of the state. Thus rehabilitation measures include not only the individual physical, mental, and occupational therapeutic techniques, but also adjustment of the social milieu of the handicapped (i.e., treatment of the whole family, adjustment of cash benefits and social services for the purpose of rehabilitation, creation of state rehabilitation agencies promoting the coordination of rehabilitation measures, etc.)" (25; Vol. II, p. 3).

The challenge has thus been laid down. How we respond may effect not only our handicapped but our whole society.

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THE PERCEPTION OF GRADIENT AND THE VEERING TENDENCY WHILE WALKING WITHOUT VISION*

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INTRODUCTION

Since 1929 investigators have studied the tendency for human when deprived of external cues to veer and to spiral when attempting to walk a straight line. Some of these previous researchers have utilized the blindfolded sighted (1, 5, 6, and 10) while others have employed blind subjects (7). The perception of gradient has been studied by animal experimenters interested in proprioceptive sensitivity, however, none of these researchers used human subjects (4, 8, and 9). In general these findings point out that humans without sight do indeed spiral and/or veer, however, exact data outlining the extent to which this occurs is largely absent. There is disagreement, however, concerning whether the veering tendency is due to perceptual (10) or to structural factors (6). The previous investigations of the proprioception of rats indicated that extreme sensitivity to gradient can be achieved by a small percent of animals after several hundred trials (4 and 8).

It was proposed in this study to investigate the tendency of the blind to veer, as well as their perception of gradient (both incline and decline). Leg length, posture, and stride length were also measured to determine if they were influential of the perceptual attributes evaluated.

EXPERIMENT

One hundred and sixty-four blind subjects were recruited from the Los Angeles area, ranging in age from 8 to 86 years of age. Included in this group were the blind-from-birth, adventitiously blind; the totally and partially blind, and individuals who reported traveling by dog, cane, and with the aid of another person. In addition, 30 sighted controls were utilized. All subjects were blindfolded, and sound cues were partially eliminated by means of ear plugs. Eight-five of the total subjects were males, their mean age was 37.75 years, while on the average the total subjects reported having had 10.58 years of schooling.

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* This investigation has been published in monograph form and was carried out under the sponsorship of the United States Department of Public Health, The National Institute of Neurological Diseases and Blindness (Grant No. NB05577-02S1), with the title: "Perceptual Thresholds of Non-Visual Locomotion." August 1965, Department of Physical Education, University of California, Los Angeles, 146 pp.

The majority of the blind subjects could be classified into nine groups based upon the cause of blindness:

Cause of Blindness	No. of Subjects
Retrolental Fibroplasia	17
Glaucoma	17
Diabetes	9
Accidental causes	7
Miscellaneous causes at birth	20
Cataracts	6
Detached Retinas	6
Retinitis Pigmentosa	7
Retinal Hemorrhage	3

The remaining subjects were blind from miscellaneous causes or reported that they had become blind from "unknown" causes. Fifty-one of the blind subjects had been blind from birth, while the 84 adventitiously blind had become blind at the average age of 39.17 years. Fifty-two (37.9 percent) reported having participated in mobility training programs while the remainder had not. Most of the subjects (103 [76.3 percent]) reported using a cane for travel, 19 (14.1 percent) reported that they used no aid or relied upon another person when traveling, while 13 (9.6 percent) traveled with a guide dog.

All subjects were blindfolded, and ear plugs were added in an attempt to keep constant auditory cues available. While the subjects were being tested on the large athletic field to determine their veering tendency, a large cloth opaque hood was placed over their head and shoulders in an attempt to eliminate light and wind cues which might have had varying influences upon the results.

To determine their veering tendency the subjects were taken a large athletic field, grided in white lines 10 yards apart; the field measured 110 yards by 140 yards. They were started in the middle of one side of the field, guided for five steps and then attempted to continue on the straight line established by these initial steps. An experimenter followed, plotting the shape of the pathway taken on a small grid drawn to scale. The subjects were given two trials.

Perceptions of gradient were evaluated by reports of the subjects while walking on a long pathway composed of seventeen risers placed end-to-end, and each measuring 4 ft by 8 ft. Level risers alternated with risers requiring the subject to walk 1, 2, 4, and 6 degrees, uphill and downhill. The subjects were requested to report continuously when they believed they were walking on a level surface, or whether they were walking up or downhill.

The subjects were given two trials on this pathway. In one trial they proceeded from risers producing gradients of 1 degree, then to 2 degrees, to 4 degrees, and then to 6 degrees (both incline and decline). On the second trial they proceeded in the opposite direction, starting first with the steeper gradients and finishing with the two risers producing gradients of 1 degree of incline and decline.

The measure obtained was the risers over which the last accurate reports were given when the subject proceeded from the steeper gradients, or the riser over which the first accurate report of incline and decline was given by the subject when proceeding from the 1 degree gradients to the steeper ones.

Stride length was measured on a long paper runner after the subject had walked across it making black marks with powder which had been previously placed on the soles of his shoes. His posture was evaluated by means of a photograph taken as he was positioned behind a posture screen composed of 2-in. squares. Leg length was measured to the nearest one-quarter in. from the front of the hip bone to the floor.

Intergroup differences in the perception of gradients were determined by comparing the percent of subjects within each group who correctly reported 1 degree of incline and of decline. Intergroup differences in the amount of veer evidenced were computed by contrasting the mean amount of rotation per 100 ft of travel by subjects within two or more groups compared. All differences reported as significant exceeded the 5 percent level of confidence.

RESULTS

1. Comparison of the direction an individual subject took on trial one and trial two on the large field revealed that the direction of veer was highly predictable ($\chi^2 = 29.52$); however, the amount of veer from trial to trial showed only a moderate correlation (+0.4 to +0.5 depending upon the group analyzed).

2. Subjects who veered twice to the left veered significantly more than did subjects moving to the right (57.41 degrees of rotation per 100 ft, versus 36.91 degrees per 100 ft). On the average the subjects rotated 36.91 degrees per 100 ft of forward movement attempted, thus swerving about 1.26 in. per step.

3. The subjects' perceptions of decline were more accurate (1 degree) than were their perceptions of incline (2 degrees on the average); and were independent perceptual attributes ($\chi^2 = 2.37$).

4. Head torsion, leg length, hand, and leg dominance were not predictive of the direction nor of the amount of veer evidenced by the subjects when attempting to walk a straight line without vision.

5. Older subjects having gone blind from glaucoma, diabetes, detached retinas, and cataracts veered significantly more than did the younger subjects blind from birth; in addition these older subjects were significantly less sensitive to decline and to incline than were the younger ones.

6. Subjects blind from birth were significantly more sensitive to decline and veered significantly less than did the adventitiously blind.

7. Sighted subjects were less sensitive to decline and, in addition, veered significantly more than a matched group of the blind. (These groups were matched by age, sex, educational level, height, and weight.)

8. No significant differences were obtained between the perceptual measures obtained from the totally blind versus those reporting themselves partially blind.

9. The subjects who had been blind from 6 to 10 years veered significantly more than did the subjects blind over 20 years.

COMMENTS AND DISCUSSION

It appeared that the veering tendency is dependent upon perceptual organization (i.e., what a person thinks is a straight pathway) rather than upon structural measures, (leg length, head torsion evidenced in a posture screening). Further evidence supporting this supposition was found when those blind for varying lengths of time are compared relative to the amount of veer evidenced. It is suggested that learning plays a more important role than does structure in determining the amount of veer evidenced, since individuals who have been blind for longer periods of time (over 10 years) were found to veer significantly less than those blind for a shorter period of time.

It would thus appear that the best method for overcoming the tendency to veer would be in helping the individual understand what walking a straight pathway feels like, or perhaps to aid him to imagine a straight line stretching before him, rather than attempting to correct postural problems, or placing a lift under one heel in an attempt to equalize leg length.

Further investigations are planned to determine the trainability of these attributes and to determine the influence of stable and moving auditory cues upon the pathways taken by individuals attempting to walk straight without vision. In addition, the perception of lateral tilt in pathways walked by the blind, the ability to accurately execute facing movements, and the perception of the curvature of curbs will be under investigation.

Based upon the data collected in this initial investigation a simplified mobility orientation test for the blind was devised, and norms were established classified by age, with which to judge the ability of the blind to walk a straight line without vision (for 150 ft), and the ability to judge gradients of 1, 2, 4, and 6 degrees both uphill and downhill. A copy of this test may be obtained from the author.

FIGURE I

COMPARISONS OF THE PERCENT OF CORRECT RESPONSES TO 1° INCLINE REPORTED BY SELECTED GROUPS

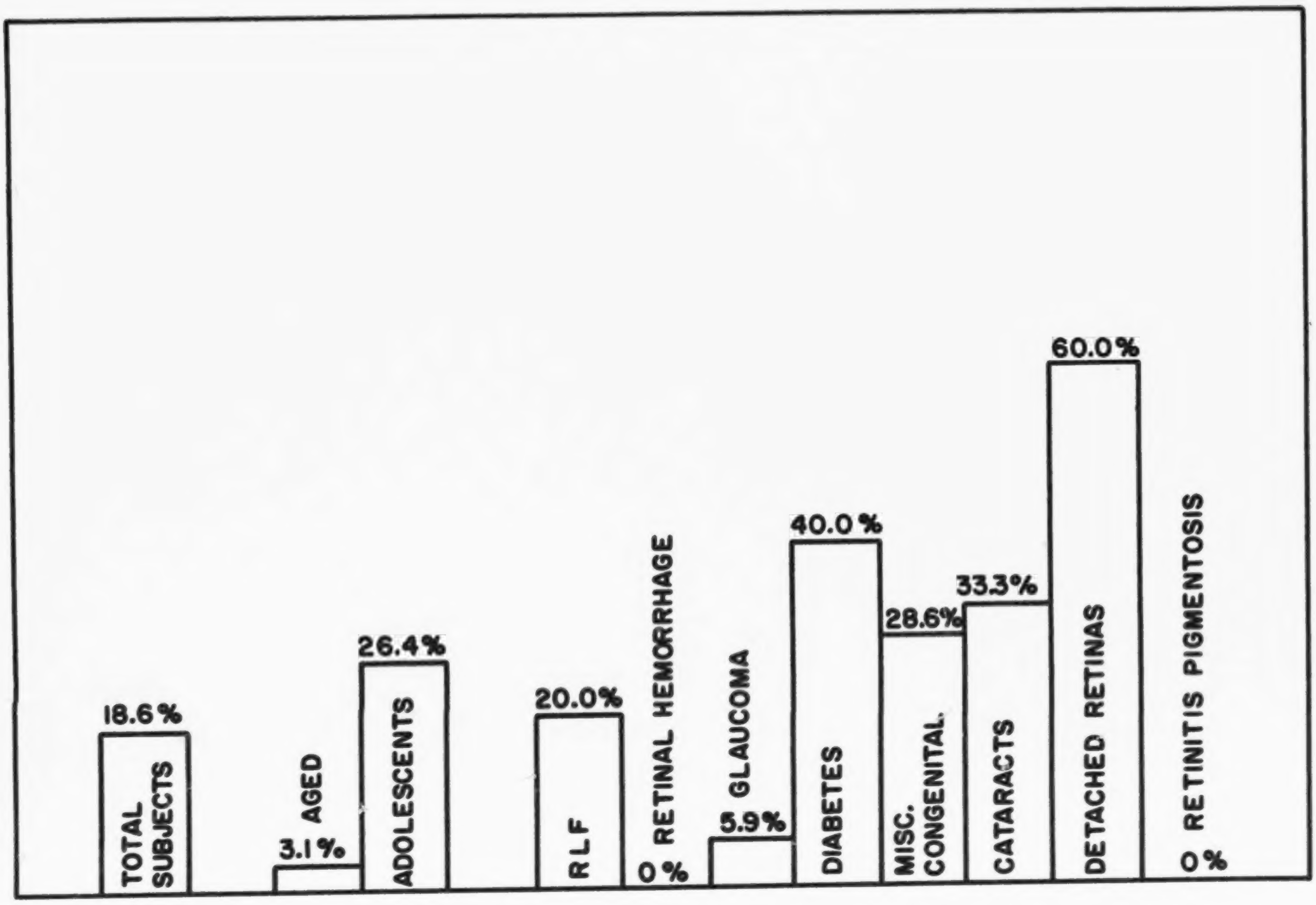


FIGURE 2

COMPARISONS OF THE PERCENT OF CORRECT RESPONSES TO 1^0 DECLINE REPORTED BY SELECTED GROUPS

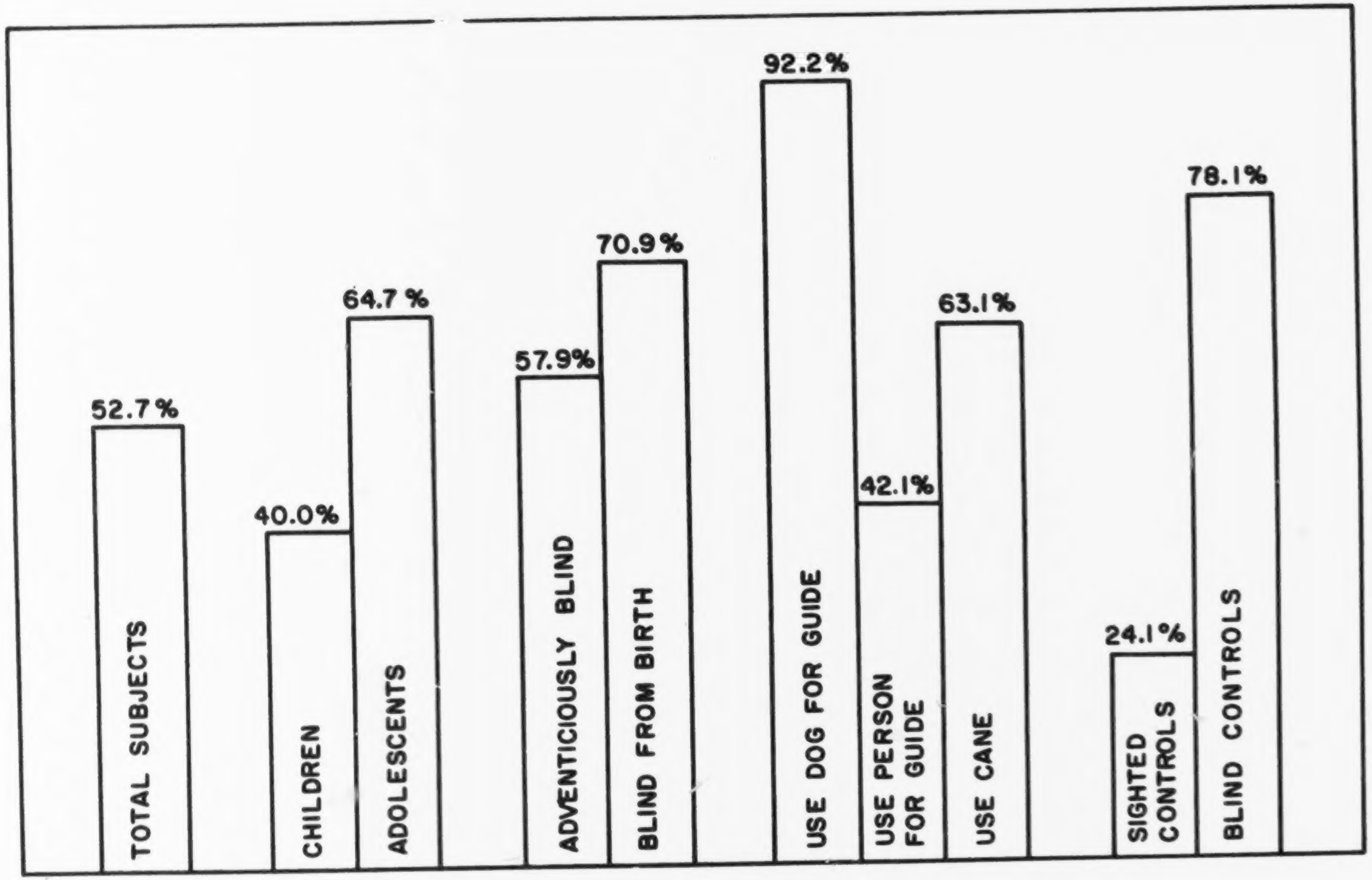


FIGURE 3

THE AVERAGE PATTERN WALKED BY SUBJECTS WHO VEERED TWICE TO THE RIGHT CONTRASTED TO THE AVERAGE PATTERN BY SUBJECTS WHO VEERED TWICE TO THE LEFT, ON TRIAL ONE AND TRIAL TWO.

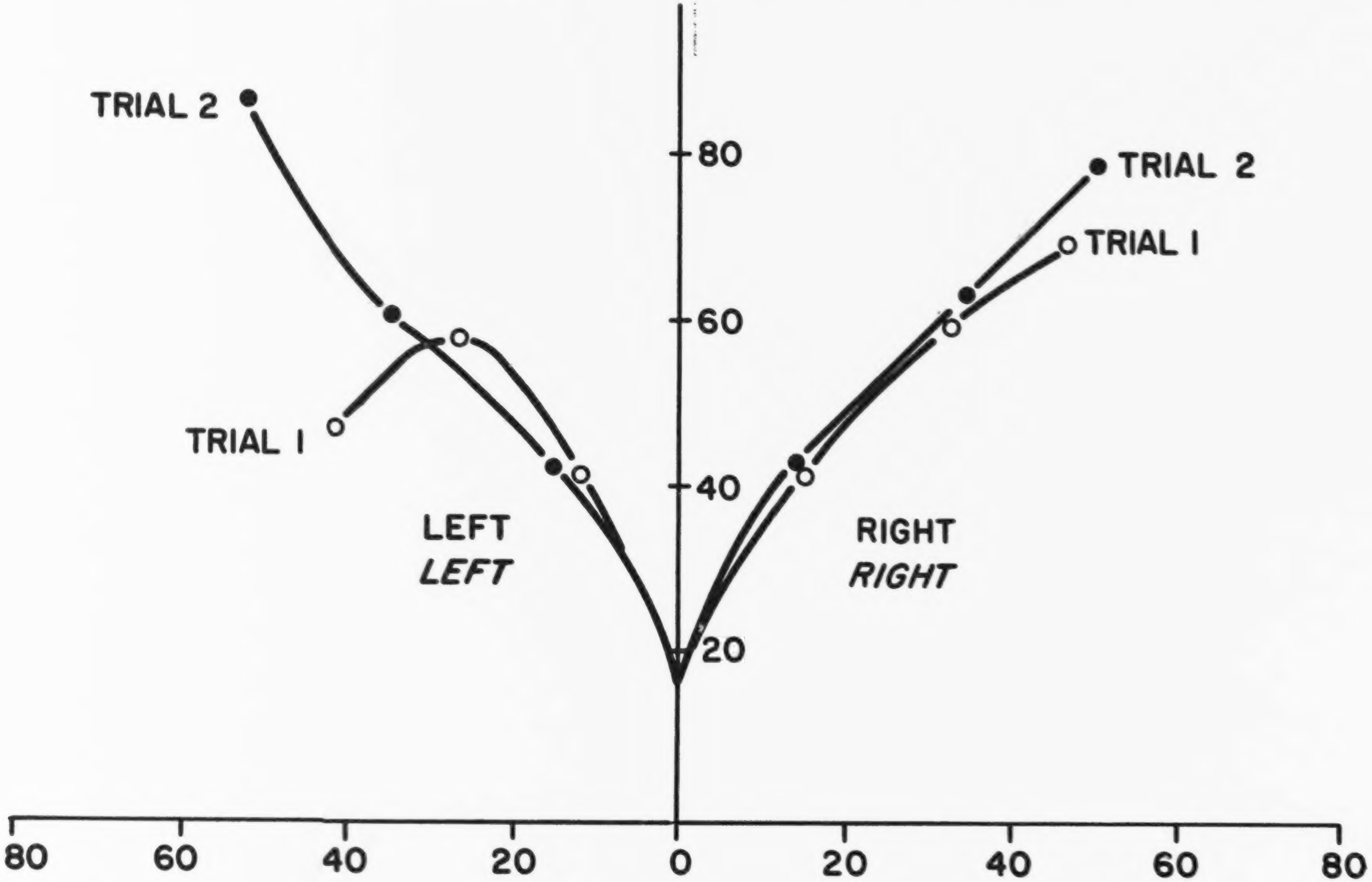


FIGURE 4

COMPARISONS OF THE PERCENT OF CORRECT RESPONSES TO SLIGHT LEFT CURVATURE (42' RADIUS) REPORTED BY SELECTED GROUPS

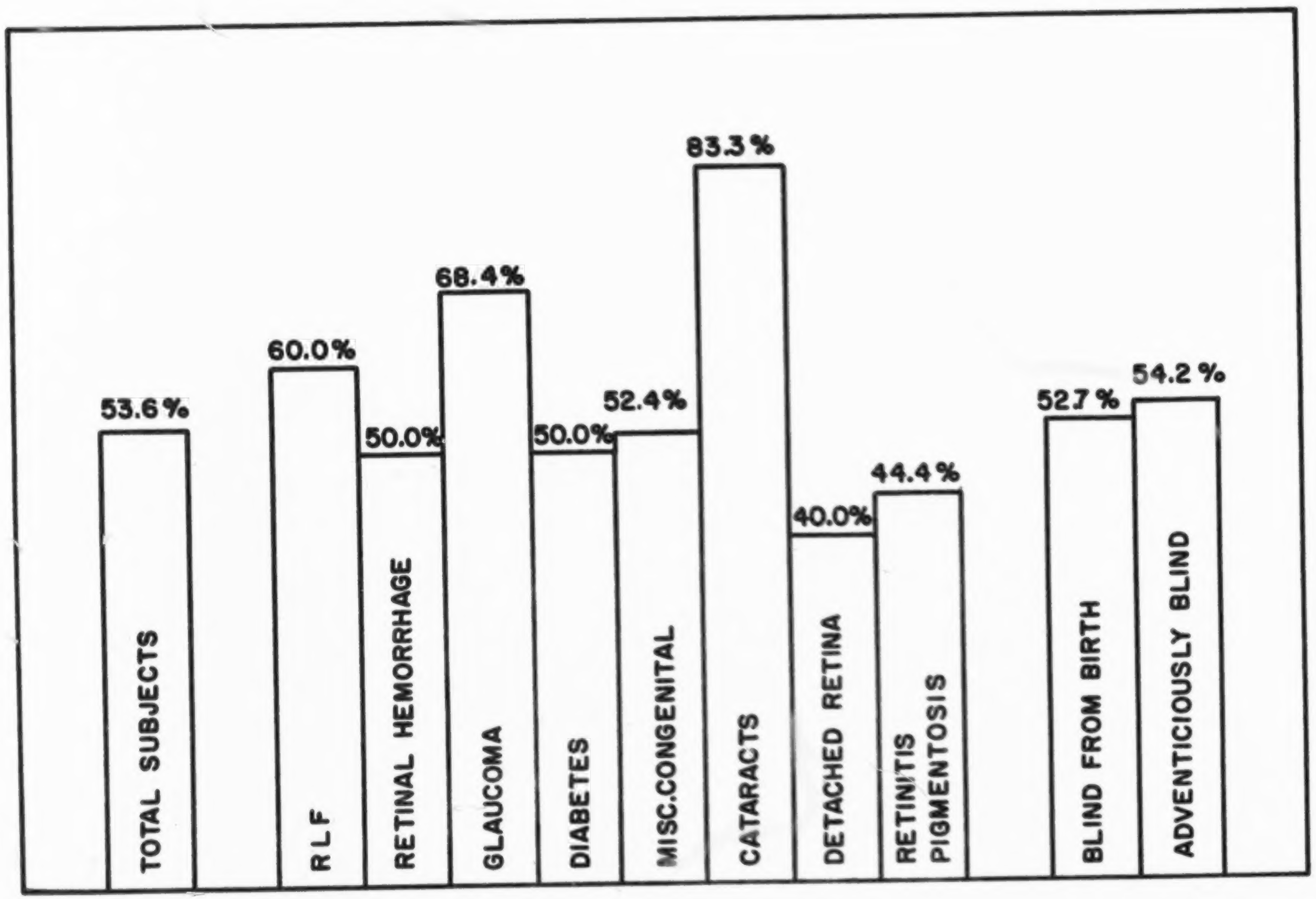


FIGURE 5

A COMPARISON OF THE PATHS WALKED BY THE TOTAL SUBJECTS ON TRIAL ONE AND ON TRIAL TWO

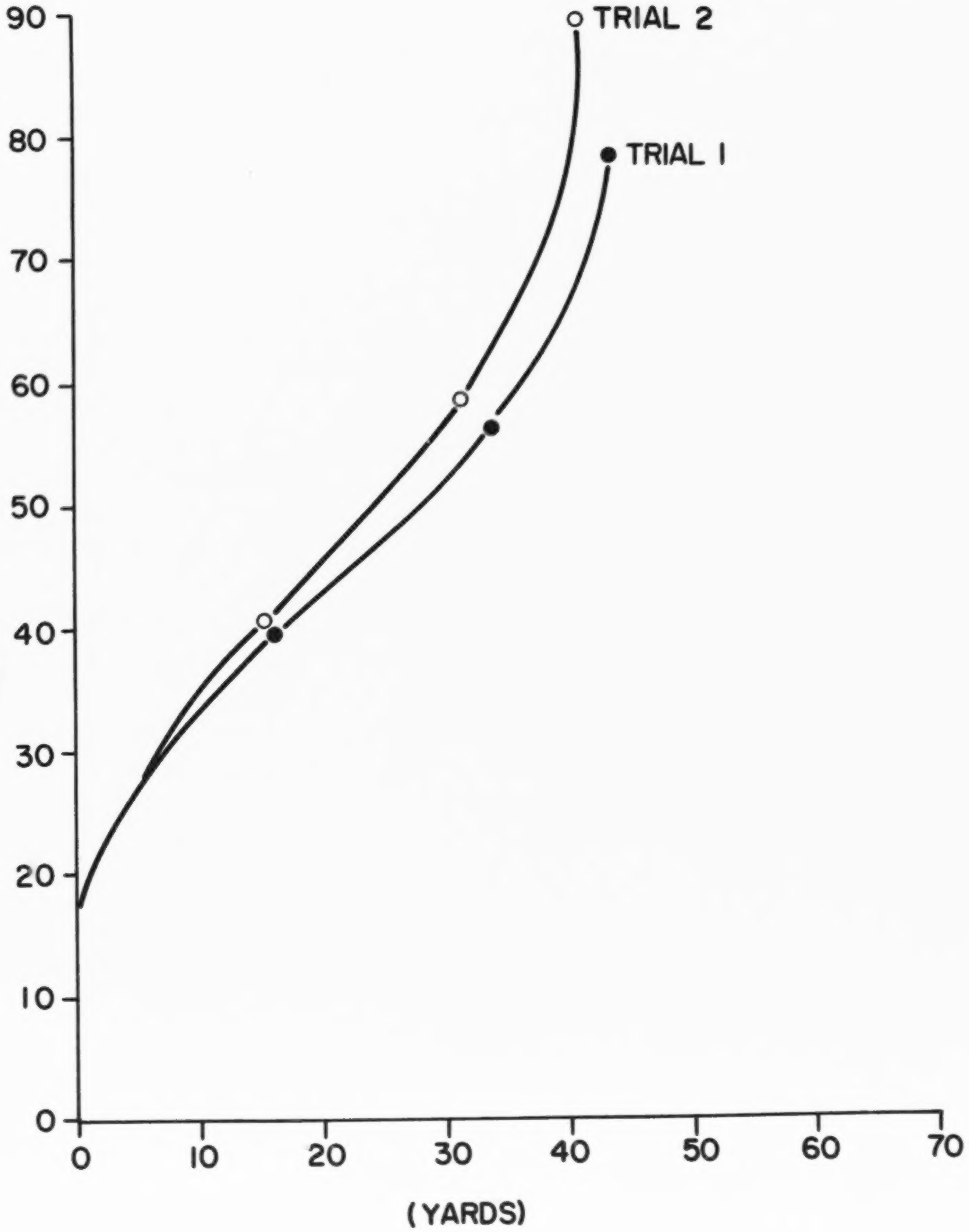


FIGURE 6

A COMPARISON OF THE PATHS WALKED BY THE BLIND SUBJECTS
WHO ROTATED TO THE LEFT AND THE SUBJECTS WHO
ROTATED TO THE RIGHT

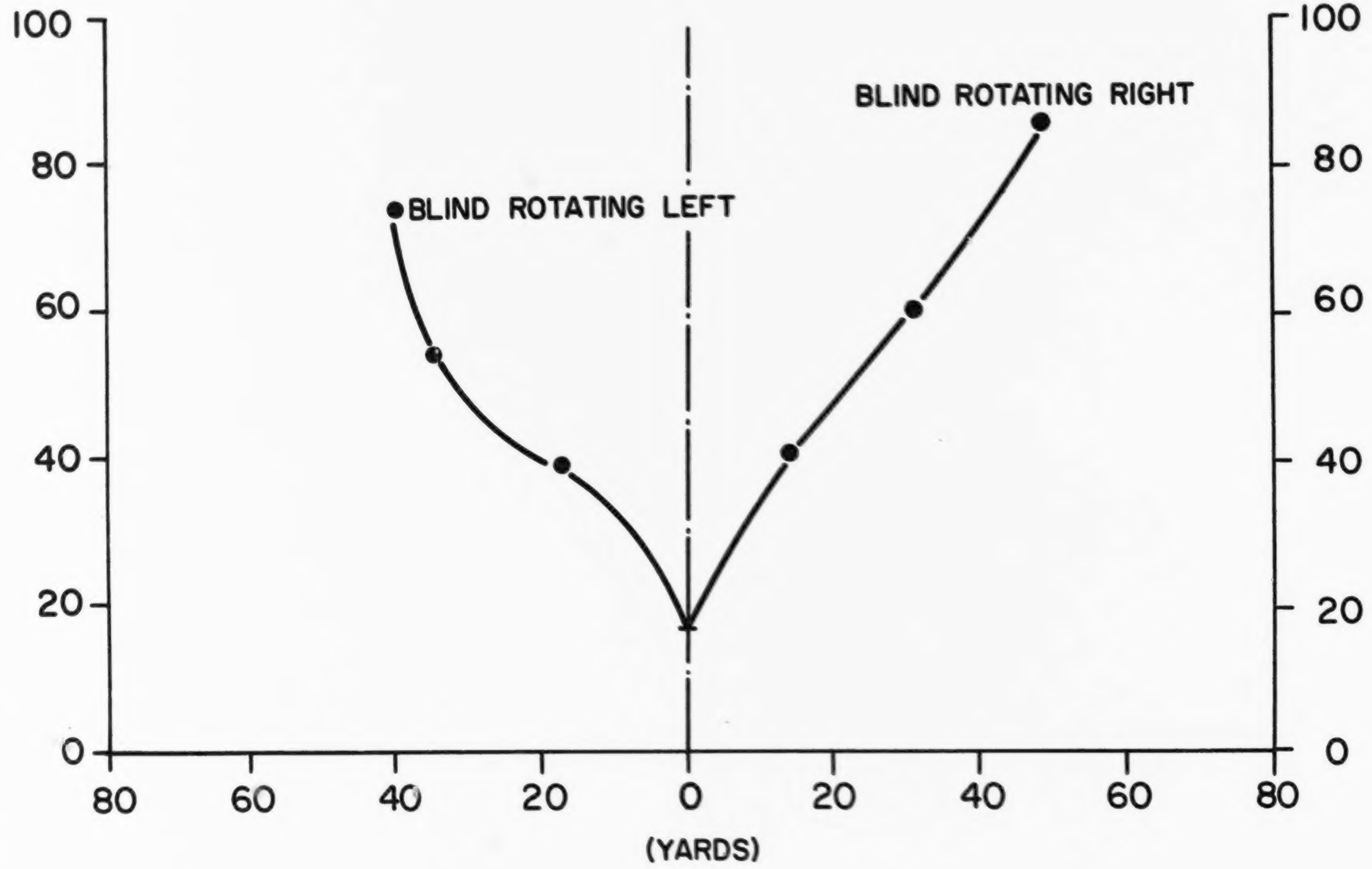


FIGURE 7

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE BLIND MALES AND BLIND FEMALES

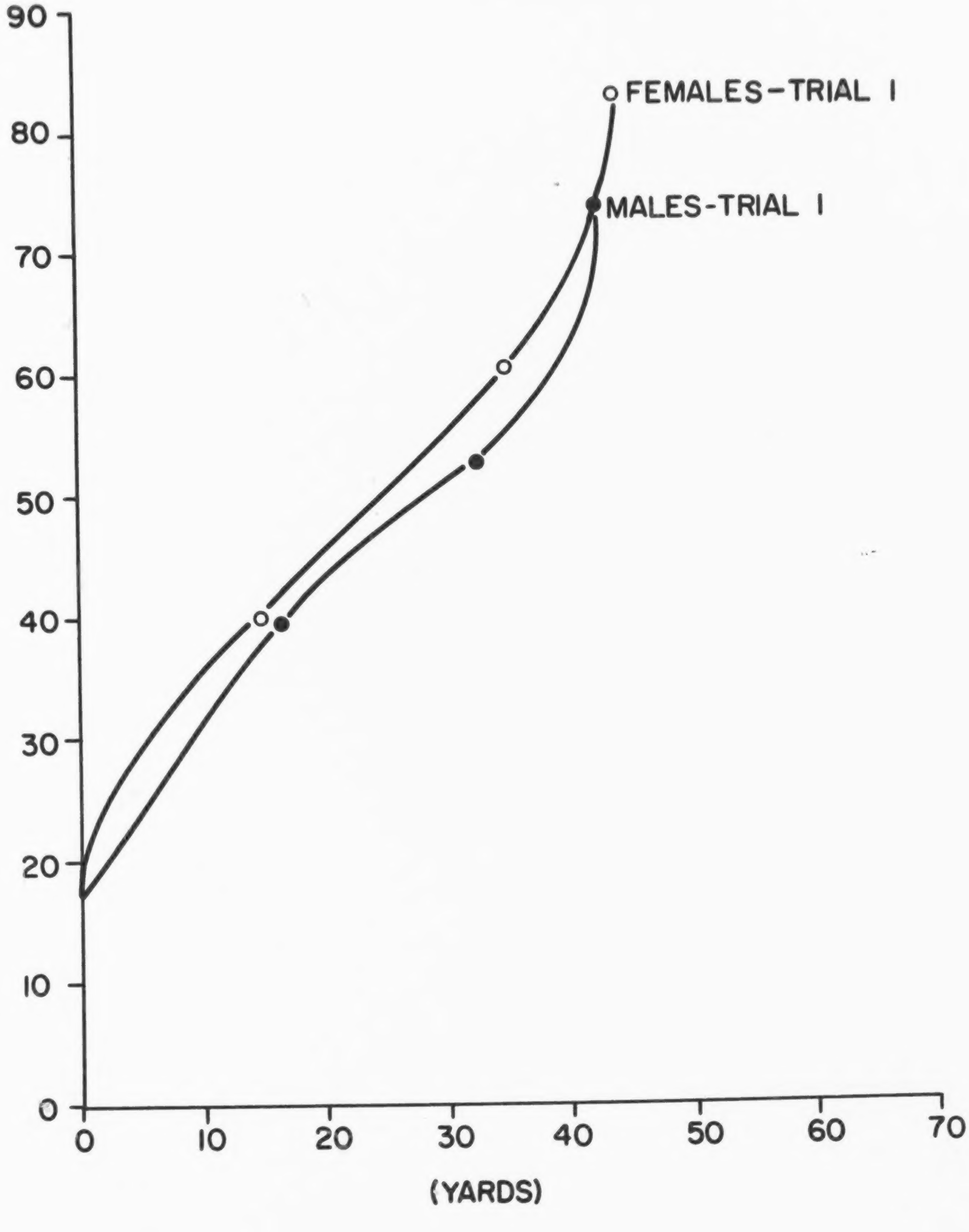


FIGURE 8

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY BLIND SUBJECTS OF VARIOUS AGES

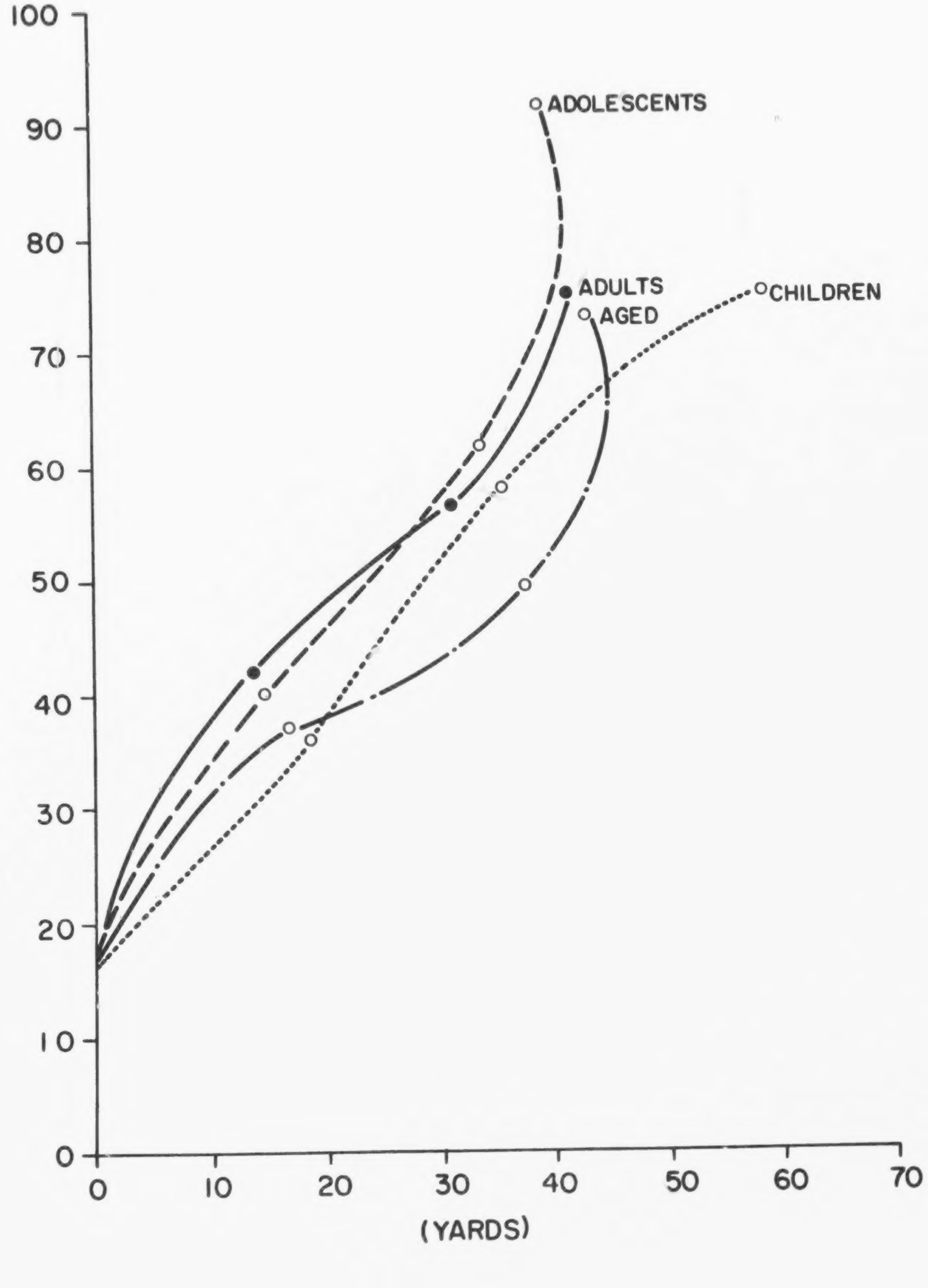


FIGURE 9

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE BLIND-FROM-BIRTH AND THE ADVENTICIOUSLY BLIND

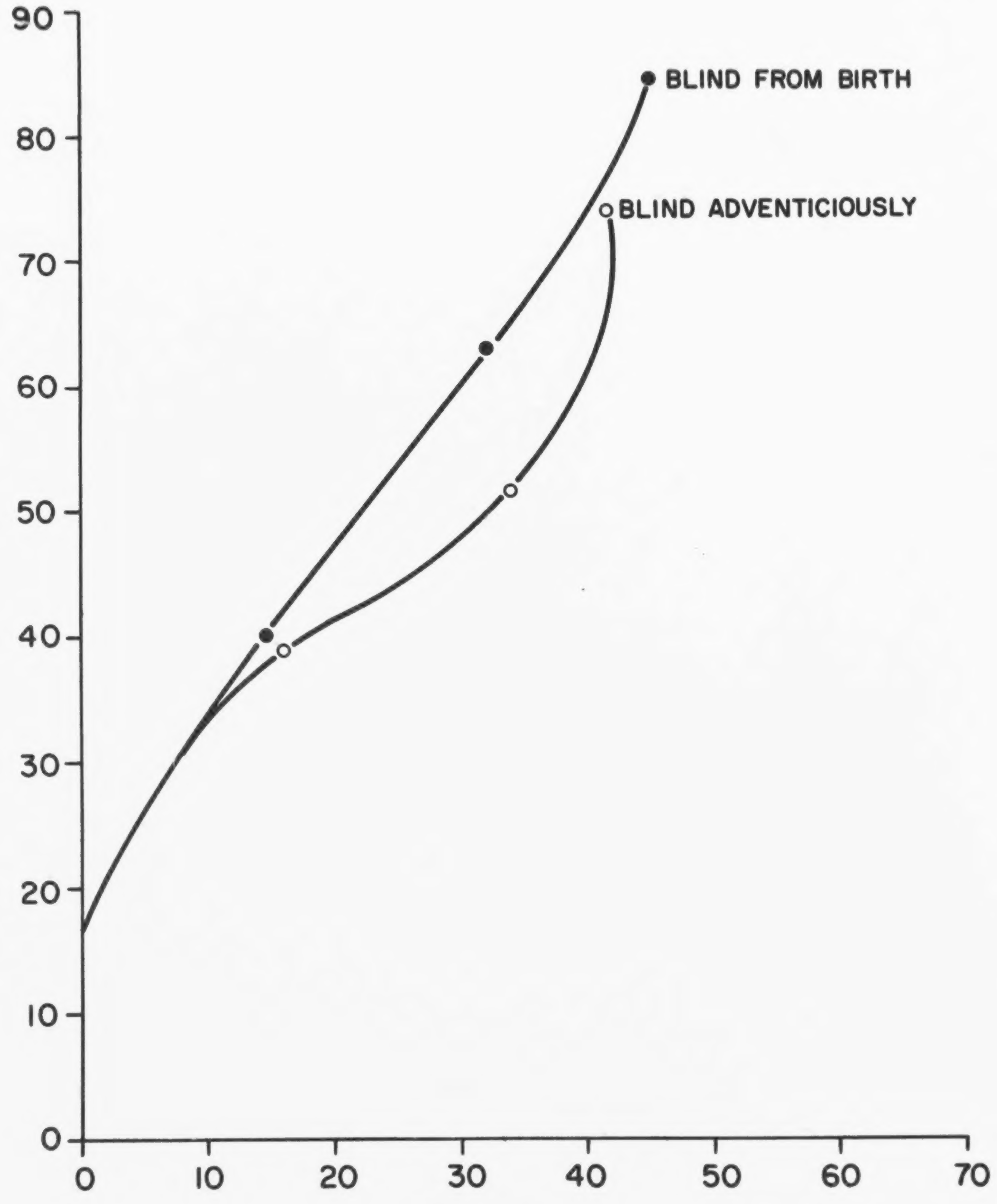


FIGURE 10

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE BLIND WHO REPORTED THEY HAD NOT PARTICIPATED IN PROGRAMS OF MOBILITY TRAINING, VERSUS THOSE SUBJECTS WHO HAD EXPERIENCED TRAINING

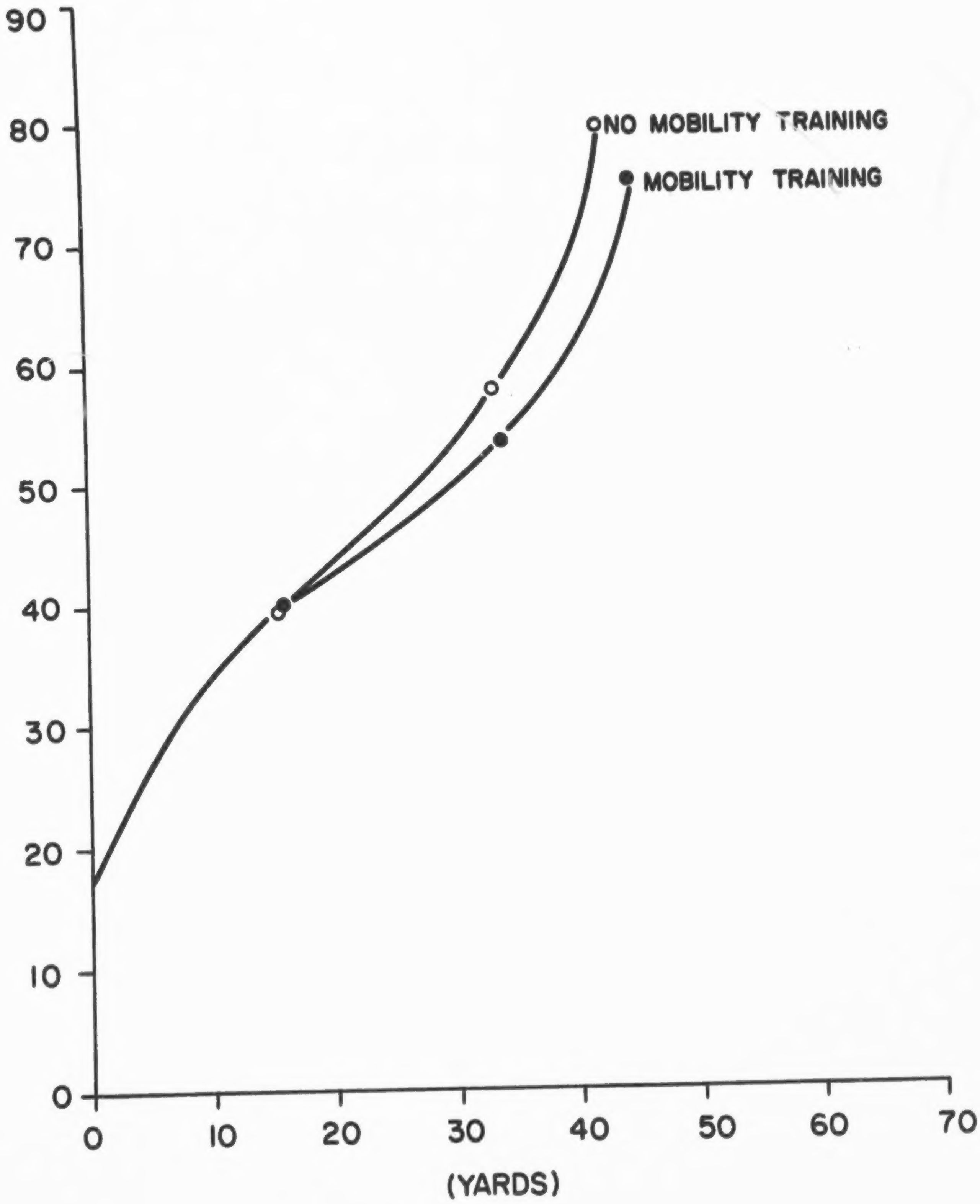


FIGURE 11

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY BLIND SUBJECTS WHO REPORTED TRAVELING BY VARIOUS MEANS

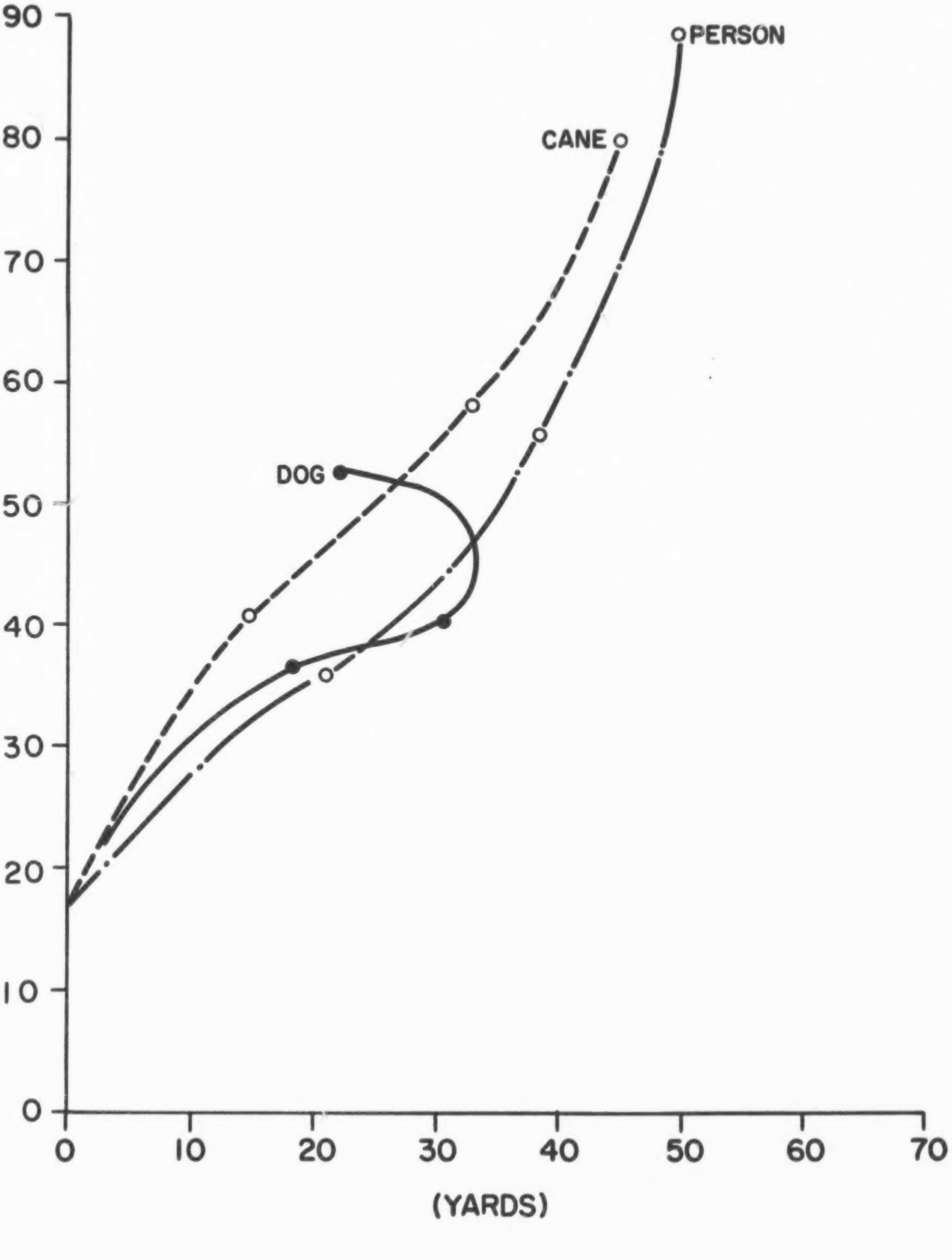


FIGURE 12

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE BLIND CONTROLS AND THE SIGHTED CONTROLS

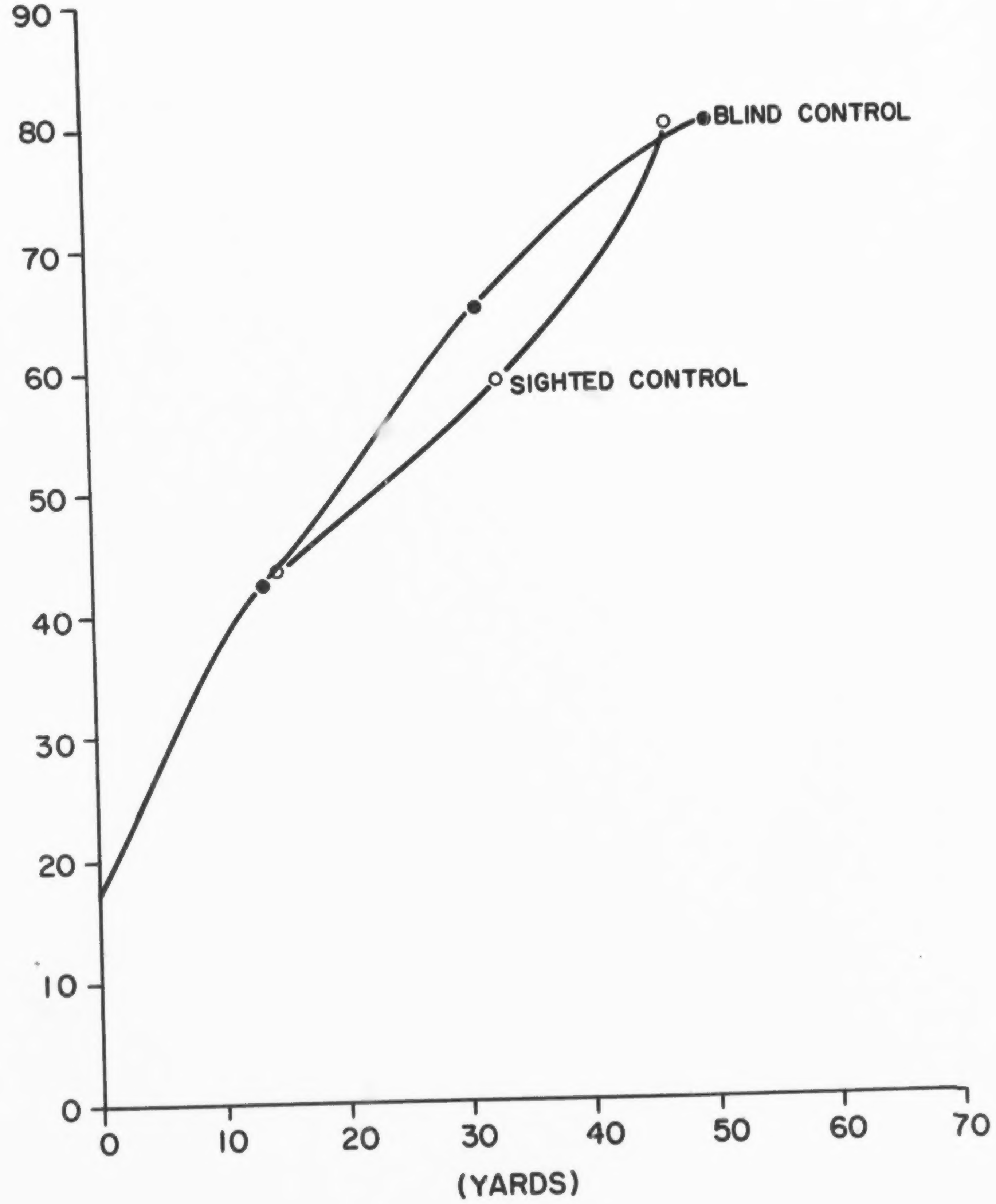


FIGURE 13

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE PARTIALLY BLIND AND THE TOTALLY BLIND

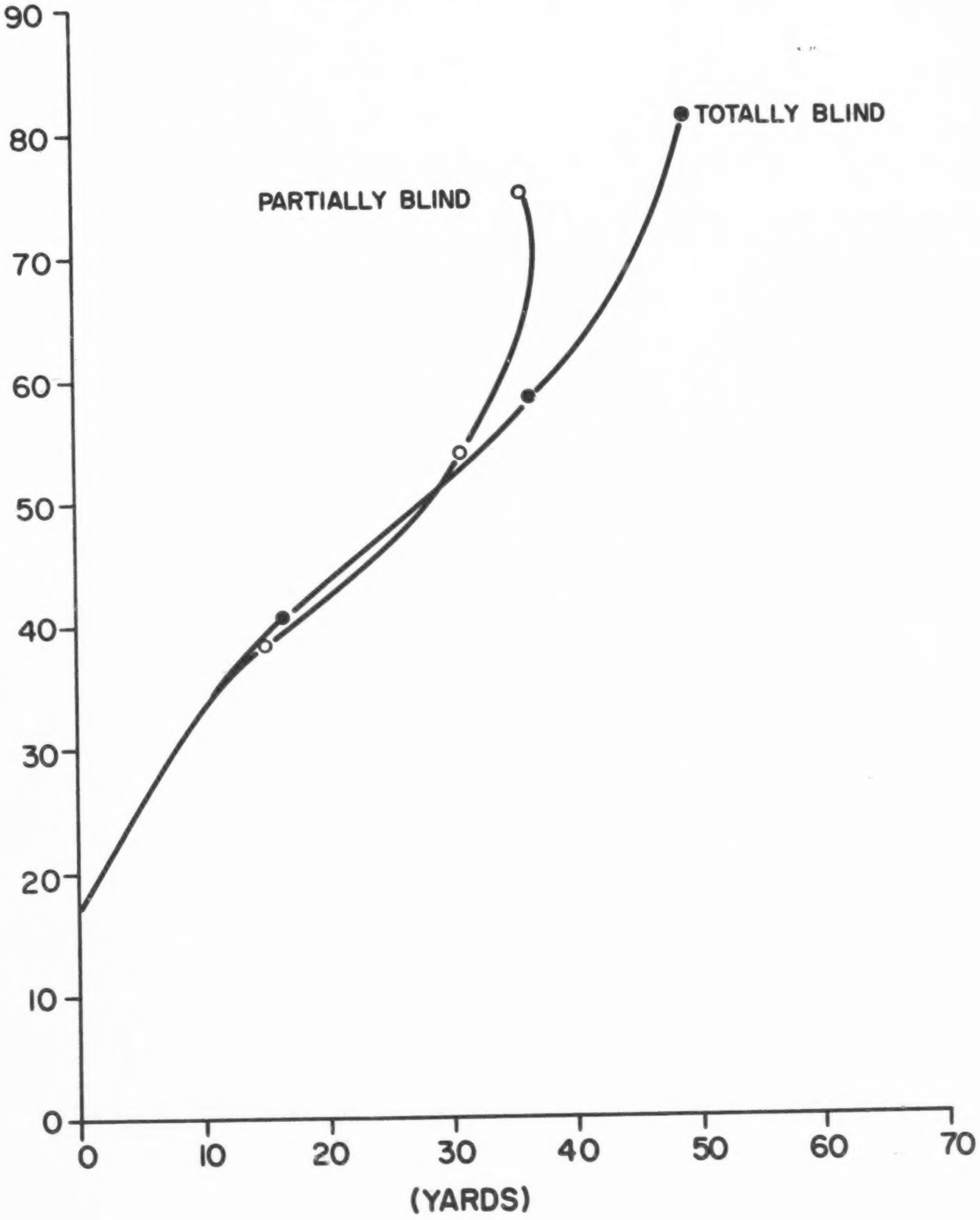


FIGURE 14

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY SUBJECTS WHO HAD BEEN BLIND FOR VARIOUS PERIODS OF TIME

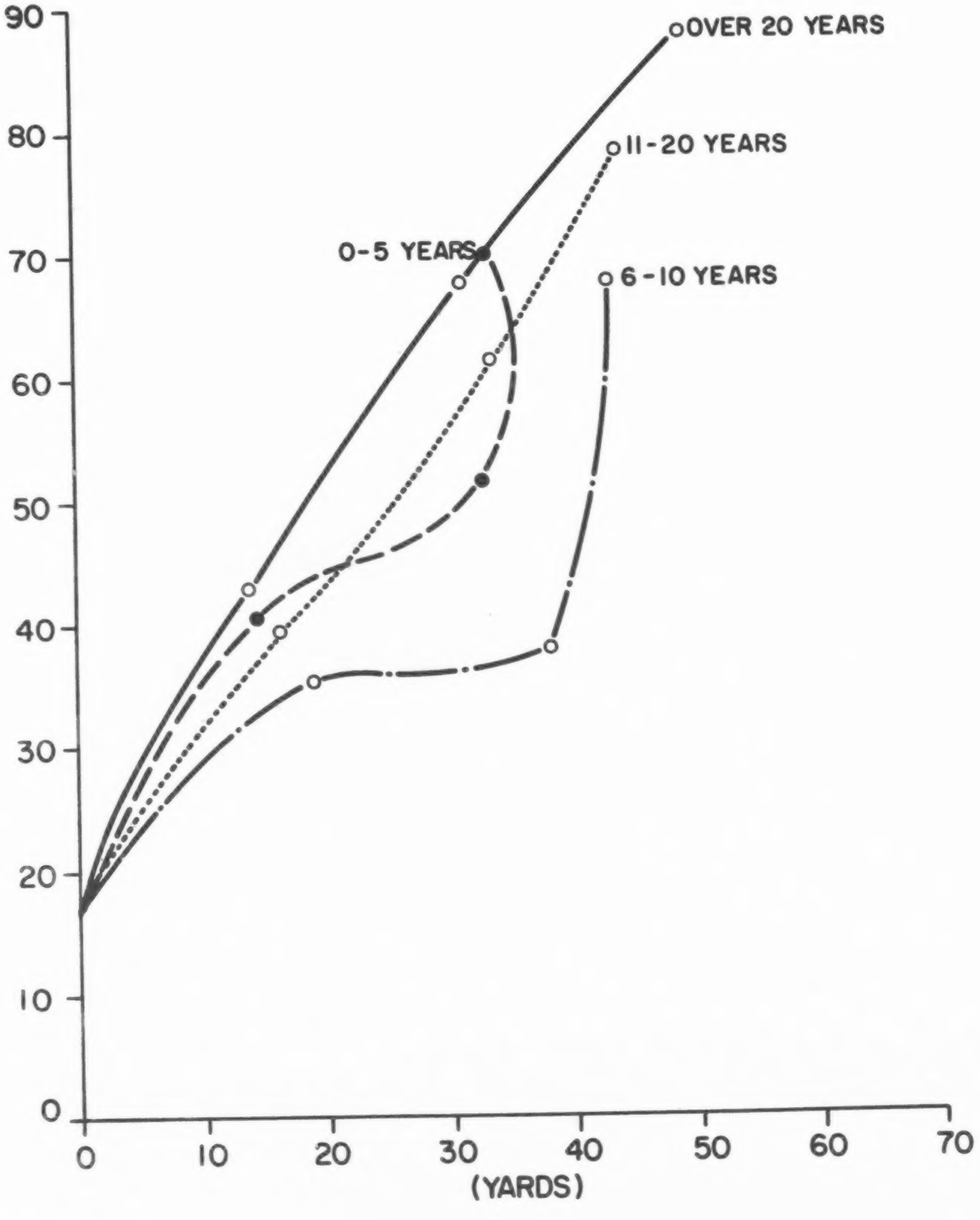
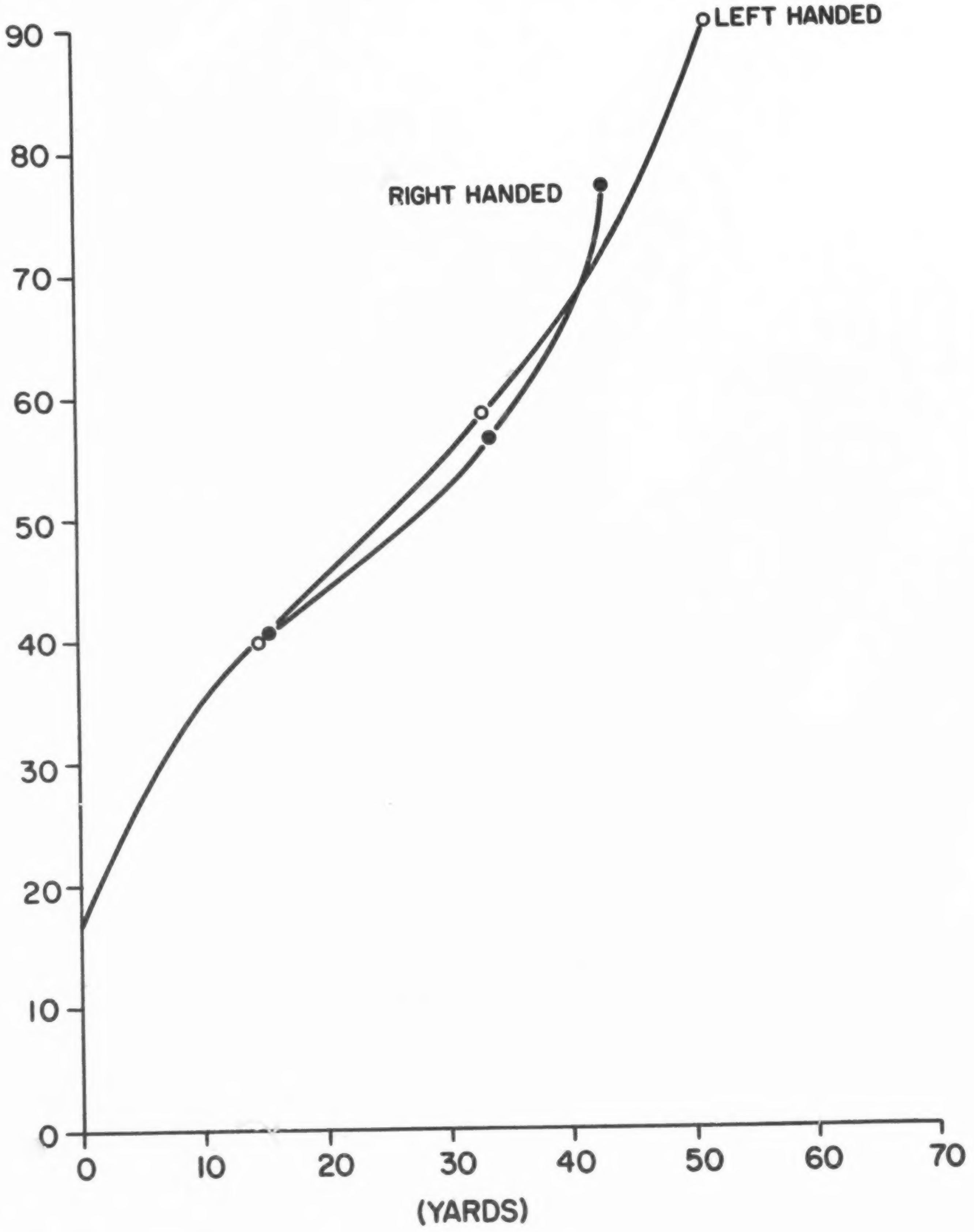


FIGURE 15

A COMPARISON OF THE PATHS WALKED ON THE FIRST TRIAL BY THE RIGHT HANDED SUBJECTS AND THE LEFT HANDED SUBJECTS



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VEERING TENDENCY AS A FUNCTION OF ANXIETY IN THE BLIND*

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INTRODUCTION

Several investigators have studied tactile and kinesthetic perceptual thresholds of the blind (2, 3, 10, 13). These researchers have been concerned with the perception of forms, straight lines and space without the aid of vision. Interest in the perception of space has led to the creation of tasks in which subjects were required to walk certain patterns which sometimes involved attempting to walk straight lines. Since it has been found that man tends to veer when attempting to walk a straight line without vision, some of the researchers have become interested in this veering tendency as it relates to the mobility training of the blind (2, 3, 10).

The purpose of the present study is to provide additional information regarding the magnitude of this veering tendency as it relates to level of anxiety in the blind. It is hoped that this may be of use to mobility trainers and others who work with the blind in training programs.

REVIEW OF LITERATURE

Anxiety

Anxiety can be defined broadly as a generalized fear or foreboding (1:169). Malmo and Davis classify individuals as anxious only if this feeling of fear is chronic (8). They found that highly anxious individuals tend to exhibit more muscular tension and a more pronounced galvanic skin response. Since these measures are often used to indicate level of arousal, Malmo and Davis believe that highly anxious persons tend to have a lower threshold for arousal. In other words, they become aroused more easily. For instance, a certain emotional verbal statement which would not af-

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* The author wishes to thank Dr. Bryant J. Cratty, Director of the Perceptual-Motor Learning Laboratory at UCLA, for the use of facilities and subjects and personnel who helped in the collection of the data.

fect a low anxiety individual might cause great excitement in a highly anxious person.

Several investigators found relationships between anxiety level and certain perceptual thresholds. In general they have found that the highly anxious are less sensitive and more variable in their responses to perceptual tests. Some researchers have found that highly anxious individuals tend to be less sensitive to "flicker" in the flicker fusion test (4, 6). Riedel compared high and low anxiety subjects in their ability to discriminate the length of two lines presented side by side (9). The high anxiety group responded a greater percentage of the time with "doubtful" answers which indicated that they could not make a discrimination between the lengths of the two lines presented. Similar differences might also be found in tasks involving kinesthetic perception.

Veering Tendency

The veering tendency in man was studied in 1928 by Schaeffer (11). He studied sighted blindfolded subjects while they were walking, driving, and swimming. When the subjects were directed to move forward in a straight line while performing any of these activities, they tended to spiral rather than move straight ahead. In other words, they veered away from the straight line after a short distance, and their paths eventually resembled a tight coil similar to the mainspring of a watch. Although right spirals were dominant, many subjects spiraled in different directions (right or left) on successive trials. There was no correlation between hand dominance and spiraling in any of the movement tasks. Schaeffer concludes that this spiraling phenomenon, which he had also observed in many other species of animals, is internally controlled by some neurological mechanism.

Lund, on the other hand, presents data which he believes support the hypothesis that the veering tendency is due to some anatomical or structural variation within individuals (7). He found that 80 percent of his subjects showed a relationship between structural dominance and veering tendency. For instance, he presents data which seem to indicate that leg length is an important factor. Supposedly, a shorter leg would cause an individual to veer to that side when walking.

However, as Schaeffer points out, individuals differ in their asymmetries, and if the veering or spiraling tendency is related to this, the spirals would be related in size and direction to each person's asymmetries. He did not find this to be true. Different sizes and directions of spirals were noted in many of the subjects, but these did not seem to correspond to such factors as leg length or hand dominance.

Two different research teams have recently studied this veering tendency in the blind. Rouse and Worchel studied subjects who were instructed to walk in a straight line on an open field. It was found that these individuals veered 11.06 degrees at 100 ft, 18.38 degrees at 200 ft, and 25.28 degrees at 300 ft. Few objects for reflection of sounds were present on this field, so removal of sound cues by the use of ear plugs did not seem to increase the veering tendency. They conclude that since this veering tendency does exist, blind individuals probably need auditory or tactile cues signifying straightness in order to walk in a straight line.

Cratty has also studied the veering tendency in the blind (2, 3). He studied subjects who were instructed to walk in a straight line on a large athletic field. These individuals rotated 36.91 degrees per 100 ft (2). He also found that the direction of the veer was highly predictable. In the second year of his study he found that walking speed was related to amount of veer. Those subjects who walked faster tended to veer less. He relates this to the subject's ability to concentrate upon the task (3). He also found that training individuals by instructing them to braille a replication of their spiral path, comparing it to a straight path, significantly decreased the magnitude of their veer at 200 ft.

PROCEDURES AND EQUIPMENT

The subjects used in this investigation were 44 legally blind individuals who reported having no effective travel vision and who volunteered to come to University of California at Los Angeles (UCLA) to be tested. They ranged in age 17 to 55, and their average age was 32. Both men and women were included in the group. Subjects were all in good health.

Taylor's Manifest Anxiety Test was used to determine the anxiety level of the subjects (12). Individuals responded by dropping cards into either a "yes" box or a "no" box in reply to the questions which were tape recorded and played to them. Scores on the test could range from 0 to 20 with scores of about 15 to 20 indicating high anxiety.

Veering tendency was measured on a level grass athletic field. The testing area measured 90 yards by 120 yards and was gridded with chalk lines in 10 by 10 yard squares. A starting point was located at the midpoint of each of the 90-yard edges. Subjects entered the testing area at one of the starting points after having walked through a straight pathway formed by two 20-ft aluminum tubes placed 3 ft high and 2 ft apart. Thus, the subjects were guided along a straight path for 20 feet and then attempted to continue walking this path on the open athletic field. All subjects received eight trials at this task, and the starting point for each trial was selected randomly. Each subject was blindfolded before he arrived at the testing area, and ear plugs were inserted and a hood placed over his head at the site of the testing to reduce light, sound, and wind cues. After the subject left the starting pathway, a stopwatch was started and the tester followed directly behind him with a small score sheet gridded to resemble the testing area. The path which the subject walked was drawn on this score sheet. Subjects were stopped when they left the gridded area or when they had walked in a complete circle. At the same time, the stopwatch was stopped and the walking time was recorded. Subjects were then given a short rest and then led to the starting pathway for the second trial.

The distance veered was measured for each subject at the point at which he had walked 100 ft, 200 ft, and 300 ft. Coordinates were recorded for each of these three points from the two axes of the grid. Also, walking speed was reduced to units of feet per second for each subject. It is assumed that during trial I subjects were still familiarizing themselves with the task at hand. Trials IV-VIII were performed under slightly different conditions in which subjects were divided into control and experimental groups to study training effects. Therefore, it was decided to average the distances veered on trials II and III for purposes of this investigation.

The reliability of the veering task was determined by Cratty (2:90). He contrasted the amount of angular rotation at 100 ft on two different trials, using blind subjects, and obtained a correlation coefficient of +0.817.

RESULTS

Scores on the Taylor test ranged from 0 to 18 with an average of 5.2 (S.D. = 4.4). This indicates that subjects were of relatively low anxiety since a high score (15 to 20) must be obtained to evidence high anxiety. Subjects in the upper and lower quartiles of this test were selected, and the two groups were compared on measures of walking speed and veering tendency. The anxiety scores of the upper quartile (high anxiety) ranged from 8 to 18, and the scores of the lower quartile (low anxiety) ranged from 0 to 2.

A Fisher t was computed between the mean distances veered by high and low anxiety groups at both 100 ft and 200 ft (5). The results are presented in Table I. No comparison of the distances veered at 300 ft was possible because many of the subjects had left the grid or walked in a complete circle before they had walked 300 ft. The high anxiety blind subjects veered an average of 12 ft more while walking 100 ft than the low anxiety subjects (Figure 1). This difference in magnitude of veer is significant

FIGURE I

COMPARISON OF VEERING TENDENCIES OF LOW AND HIGH ANXIETY GROUPS

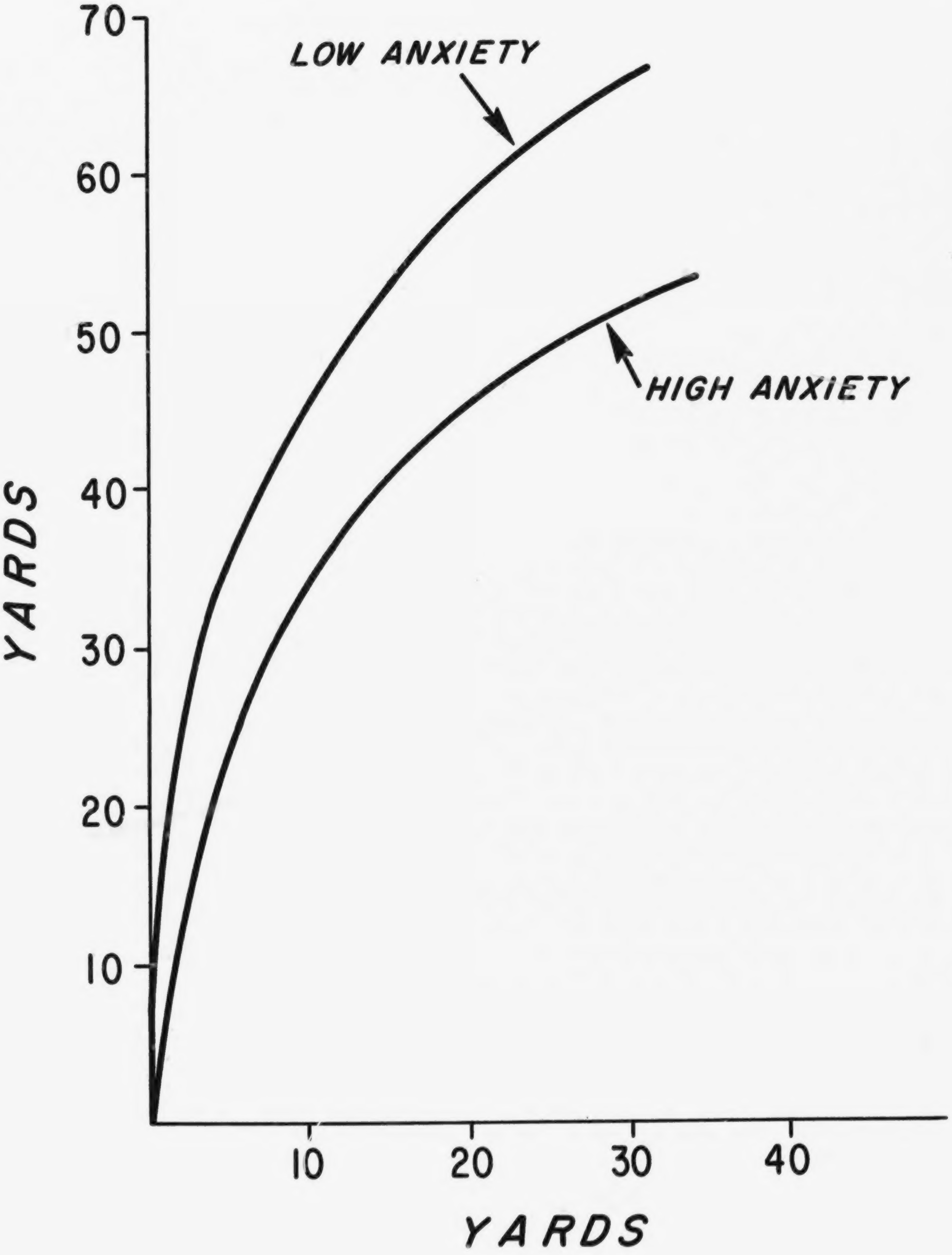

TABLE I

AMOUNT OF VEER AS A FUNCTION OF ANXIETY

	GROUP	M	S.D.	Σx^2	df	t
100'	High Anxiety	23.4'	8.39	2607	20	2.18*
	Low Anxiety	11.4	15.30	775		
200'	High Anxiety	81.0	16.5	14638	20	0.80**
	Low Anxiety	65.0	36.4	29847		

*Significant at the .05 level
**Not significant at the .05 level

at the 0.05 level. There was no significant difference between the distances veered by the two groups at 200 ft.

Tests of significance between the standard deviations of the two groups were carried out to determine whether there were significant differences in the variability of the scores (5). Results of this procedure are presented in Table II. There was no significant difference in the variability of the scores of the two groups at 100 ft. However, at 200 ft the low anxiety group was significantly more variable than the high anxiety group.

A Fisher t was computed between the mean walking speeds of the two groups (Table III). It was found that the high anxiety subjects walked an average of 1.02 feet per second slower than the low anxiety subjects. This difference is significant at the 0.05 level. A test of significance between the standard deviations of these scores resulted in insignificance (Table IV).

A multiple correlation was carried out to evaluate the effects of the combination of anxiety and walking speed upon the magnitude of the veering tendency (5). Results are presented in Table V. The correlation coefficient equals +0.51 which is moderate.

TABLE II

COMPARISON OF STANDARD DEVIATIONS OF VEERING SCORES

GROUP	100'				200'			
	σ	σ_σ	σ_{σ_d}	t	σ	σ_σ	σ_{σ_d}	t
High Anxiety	8.39	1.78	3.66	1.89**	16.5	3.52	8.5	2.32*
Low Anxiety	15.3	3.26			36.4	7.75		

*Significant at the .05 level
**Not significant at the .05 level

TABLE III

WALKING SPEED AS A FUNCTION OF ANXIETY

Group	M	S.D.	Σx^2	df	t
High Anxiety	3.52	.90	8.94	20	2.86*
Low Anxiety	4.54	.62	4.98		

*Significant at the .05 level

TABLE IV

COMPARISON OF STANDARD DEVIATIONS OF WALKING SPEEDS

GROUP	σ	σ_σ	σ_{σ_d}	t
High Anxiety	.90	.191	.323	0.50
Low Anxiety	.62	.132		

*Not significant at the .05 level

TABLE V

MULTIPLE CORRELATION: PREDICTION OF MAGNITUDE OF VEER FROM COMBINATION OF ANXIETY AND WALKING SPEED

Variable	ANXIETY	WALKING SPEED	VEER
ANXIETY	---	-.32	.22
WALKING SPEED	-.32	---	.51
VEER	.22	.51	---

R= +.51

DISCUSSION

It should be noted that only two of the subjects received scores on the Taylor anxiety test which were indicative of high anxiety. This would seem related to the fact that subjects volunteered and were willing to come to UCLA to be tested. Few high anxiety individuals would probably be willing to do this. Therefore, the high anxiety group included subjects with scores on the Taylor test as low as 8. A more extensive study of the perception of space by extremely high and low anxiety blind individuals might be interesting. Greater differences in the veering tendencies of the two groups might be found, and the differences at 200 ft might even be significant.

However, the fact that there was a significant difference in the mean distances veered at 100 ft and no significant difference at 200 ft seems to lend some support to Schaeffer's theory that this veering tendency is due to some internal neurological mechanism rather than to any external anatomical asymmetry. Perhaps by the time the subjects had walked two hundred feet, regardless of their anxiety level, they were concentrating less upon the task, as discussed by Cratty and Williams (3). Therefore, this internal veering mechanism might have "taken over" and controlled the spiraling of both types of individuals.

Because the high anxiety group *did* veer significantly more at 100 ft, perhaps clients in this catagory need special attention and extra training at the beginning of mobility training sessions and/or whenever they are being trained to walk short distances. However, it seems that as the session progresses and as clients begin learning to walk longer distances, both types of blind individuals could be treated with more similarity.

Cratty and Williams found that the faster their subjects walked, the straighter were their paths during the veering task (3:62). The data presented here also indicate this. It was found that the high anxiety subjects (who veered significantly more at 100 ft) were also significantly slower walkers. Walking speed and amount of veer at 100 ft were also found to be moderately correlated (+0.51). Perhaps mobility training should include helping the highly anxious individuals, and others with slow walking speeds, to walk faster. Of course, limits to the speed of walking must be imposed for safety, but slightly accelerated speeds might allow some blind individuals to walk more accurately.

In the present study there was a moderate multiple correlation between the magnitude of the veering tendency and the combination of anxiety and walking speed (+0.51). However, this combination of variables seems to be a no better indicator of amount of veer than is walking speed alone. As seen from the Fisher t-tests in this investigation, though, significant differences between the extreme quartiles of the anxiety continuum can be uncovered. Since most individuals would probably score in the middle ranges on the anxiety test, however, no accurate prediction about the magnitude of their veer or their walking speed could be made from these anxiety test scores (Table V). Better predictions could be made about individuals with extremely high or low anxiety scores (Tables I, II, III, IV).

Results of this study seem to corroborate, in part, the findings of other investigators who have studied the perceptual abilities of high and low anxiety individuals (4, 6, 9). As stated previously, these researchers found that the highly anxious are less sensitive and more variable in their responses to perceptual tests. In the present study, the high anxiety group was less sensitive to the concept of "straightness" at one hundred feet. However, there was no significant difference in the variability of the walking speeds or veering tendencies of the two groups at one hundred feet. Contrary to the findings of the above researchers, the low anxiety group was significantly more variable in magnitude of veer at two hundred feet than in the high anxiety group.

Perhaps mobility trainers and others who work to train the blind should arrange to have their clients take some type of personality test before training is started. This would give additional information which might prove useful in the course of the training. Naturally, many persons who are in constant contact with people become experts at sensing certain types of extreme personalities. There might be some cases, however, in which the added information from a test would be helpful.

SUMMARY

1. There was a significant difference between the mean distances veered by high and low anxiety blind subjects at 100 ft. The high anxiety individuals veered an average of 12 ft farther from the straight line which they were instructed to walk.

2. There was no significant difference between the mean distances veered by high and low anxiety subjects at 200 ft.

3. There was no significant difference in the variability of the veering tendency scores at 100 ft. However, the scores of the low anxiety group were significantly more variable at 200 ft.

4. A multiple correlation between the magnitude of veer and the combination of anxiety and walking speed yielded a moderate coefficient of +0.51.

5. The low anxiety individuals walked an average of 1.02 ft/second faster than the high anxiety subjects. This difference was significant.

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INFORMATIVE TACTILE STIMULI IN THE PERCEPTION OF DIRECTION*

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INTRODUCTION

Symbols have traditionally been treated as forms of psychologically neutral "signs" or "signals" to which meanings accrue via association. The process of strengthening such associations has usually been assumed to be some conditioning process. That such processess *can* occur is supported by a voluminous literature. But the assumption that this is *the* way in which symbols acquire meanings, and interest in the processes themselves, have led to a relative neglect of the role of stimulus properties of symbols possibly affecting the perception or apprehension of symbolic meanings.

Several theoretical viewpoints have directly or indirectly questioned the "signal" approach to symbology, entertaining the possibility that the structure of a symbol may to some extent determine its perceived meaning. *Gestalt* psychologists were among the first to discuss the notion of "physiognomic characters" of objects, involving emotional meanings of perceptual configurations and resemblances of qualities perceived through different sense modalities (Koffka, 1935 [11]; Koehler, 1947 [10]). An example of the latter is the famous "takete-maluma" demonstration (Koehler, 1947 [10]). Ryan (1938) pointed up the role of physiognomic properties and spatial-temporal patterns in the apprehension of several kinds of objects and events (15). More recently, Werner and Kaplan (1963) have again questioned the usual treatment of symbols as arbitrary vehicles for meanings, calling for examination of the structural properties of symbols (20).

> "The function of representation is a constitutive mark of a symbol; it distinguishes anything qua symbol from anything qua *sign*, *signal*, or *thing*. Signs and signals are elicitors (or inhibitors) of action; they lead one to anticipate rather than

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* Some of the findings of Experiment 1 were reported briefly and in another form in Schiff (1965). The research reported here was supported by Grant RD-1571-S from the Vocational Rehabilitation Administration, Dept. Health, Education, and Welfare, to Recording for the Blind, Inc.

> to represent an event. In our view, therefore, symbols can never be considered a mere species of the genus 'sign.'
>
> "When a symbolic vehicle is taken to 'represent' a referent, it is our view that the vehicular structure functions to 'depict' or 'reveal,' through some sort of correspondence or analogy, the connotational structure of the referent" (Werner and Kaplan, 1963 [20, pp. 13-15]).

These authors then propose a theory of symbol formation based upon intentional acts, and genetic-developmental theory.

Gibson (1959, 1962, 1966), in recent theoretical views, has proposed that perceptual stimuli ordinarily contain information in their structure, and are therefore neither arbitrary nor signals in the true senses of the terms (6, 7, 8). While questioning the associational view of symbolic meaning, he further states:

> "Even in the case of symbols, then, it can still be asserted that there are discoverable properties in stimulation to which the meaning of the symbol corresponds" (1959 [7, p. 487]).

In his latest book, however, Gibson classifies symbols among those vehicles having arbitrary referents (1966 [8, p. 235]).

In addition to the above theoretical treatments, several empirical studies have borne on the problem of symbols as sources for informative stimuli. Fitts and Seeger (1953) found that compatibility between stimulus and response facilitated the learning of S-R contingencies (5). Loucks, in Chapanis, Garner and Morgan (1949), utilized a stationary artificial horizon with a rotating airplane silhouette to represent aircraft orientation, finding it superior to the conventional display utilizing a stationary silhouette and rotating horizon. The more efficient display reflected the conceptual situation - a stable horizon and "free" aircraft - in a more direct fashion (2). A related approach has been broached in displays such as the Contact Analog (Carel, 1961 [1]), which uses information in essentially the same form as that used in visual "contact" flying, rather than translating it into an arbitrary symbology. These approaches represent further use of symbolic displays as stimulus sources *specifying* their referents rather than *signaling* them. If stimuli do have informative properties, it would appear desirable to capitalize on them when developing symbolic displays. Although the meanings of many symbols have been well established by convention (as in mathematics, electronics, etc.), there are many cases in which the structural properties of symbols could be useful, especially where new symbolic vocabularies are to be constructed.

Most symbols are constructed as sources of stimuli to be picked up with the visual or auditory systems. However, Jenkins (1952 [9]) studied tactual shapes for aircraft control knobs; and others (Morris and Nolan, 1961 [12], 1963 [13]; Nolan and Morris, 1963 [14]) have been studying various areal, linear, and point symbols for tactile presentation to blind persons. However, virtually none of the tactile research has taken advantage of the opportunities afforded by informative tactile stimuli.

The present research grew from the need to develop means of efficiently presenting information contained in textbook diagrams to blind students. Many of these diagrams (as surveyed in several technical areas) contained *arrows*, usually used to convey the information of *direction*. In the construction of raised line diagrams, the visual shape of arrows was translated into tactile information by reproducing arrows as raised dotted or solid lines to be scanned with the fingertips. Informal observations indicated that many blind students had difficulty in perceiving such "visual" arrows as symbols indicating direction. This finding has been independently confirmed by Wiedel in 1965 (21). It was hypothesized that a tactile symbol specifying direction without reference to the visual symbol would be more meaningful and useful to the blind observer than the conventional visual symbol presented in tactile form.

A means was sought for imparting information pertaining to direction using information geared to the tactile perceptual system. Tactile here refers to "tactile-kinesthesis" (Fisher, 1964 [4]), implying "active" rather than "passive" touch (Gibson, 1962 [7]). A symbol was developed having the structural property of *directionality* built into it, rather than arbitrarily assigned. Direction was designed to become evident in scanning the raised material back-and-forth with the fingertips. The tool for producing the symbol is shown in Figure 1, and an enlarged cross-section of the symbol is shown in Figure 2. Scanning the tactile symbol is shown in Figure 3. Note that if the pattern is scanned from left to right, for each pattern unit, tactile pressure gradually increases, followed by a drop-off. This gradient of pressure change is repeated for each unit, leading to the percept of a *smooth* bumpy line. Conversely, when the pattern is scanned from right to left, the tactile pressure increases suddenly, followed by a gradual decrease, leading to the percept of a *sharp* bumpy line. In terms of proximal stimulation then, the ordered sequence of digital skin deformations is inversely related, and dependent upon the direction of scan (see Figure 3).

Since the symbol described above provided different stimuli for different directions of active touch, it was predicted that blind persons would be able to detect such a difference. In accord with an analogy of stroking fur or a saw blade, one might expect that the sharp scan would imply away from, and the smooth scan - towards. It was predicted that the tactile symbol would be more efficient and meaningful for unsighted persons than the translated

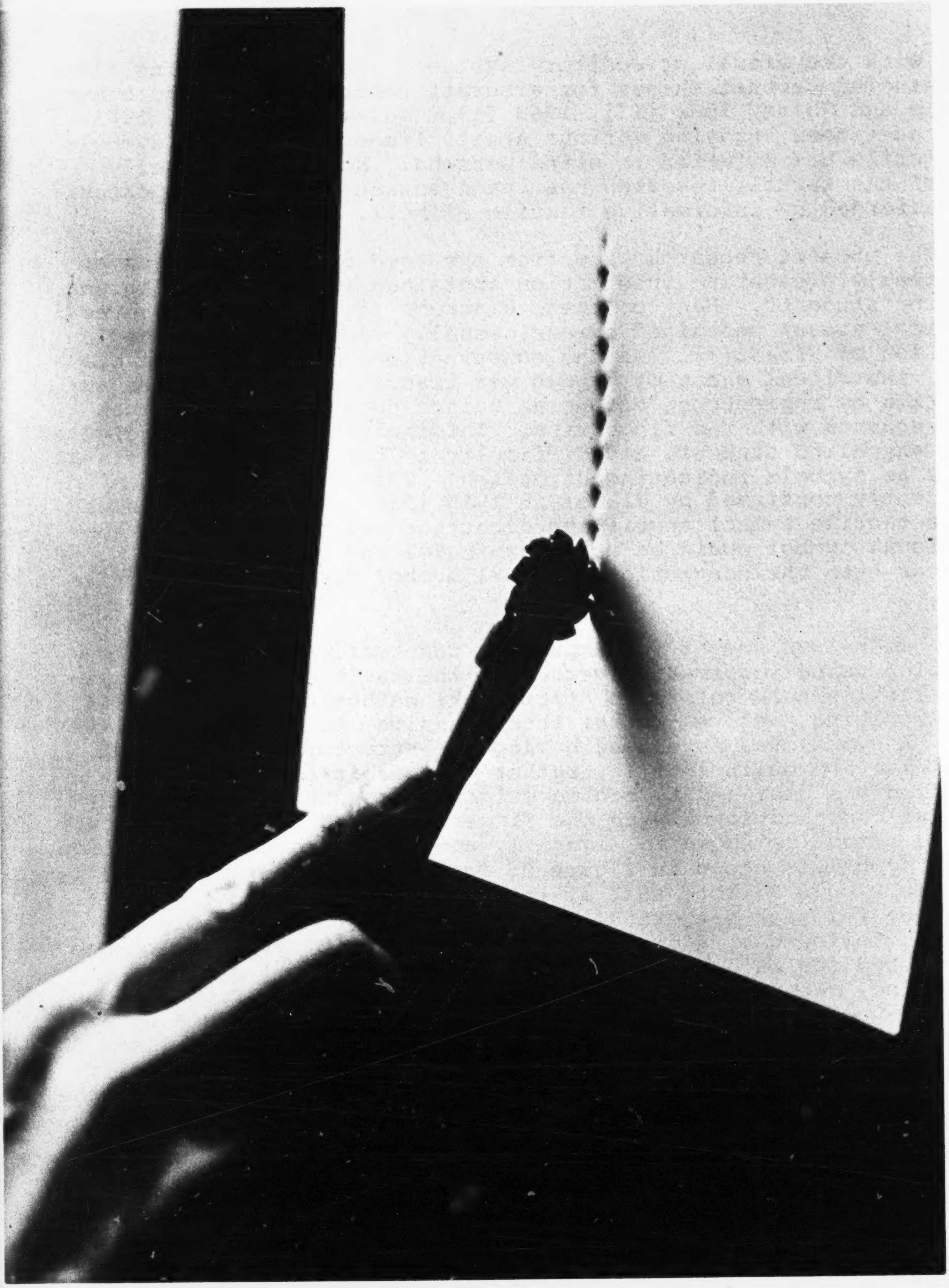

Figure 1. Tactile Symbol Tool Being Used to Make an Impression on an Aluminum Sheet.

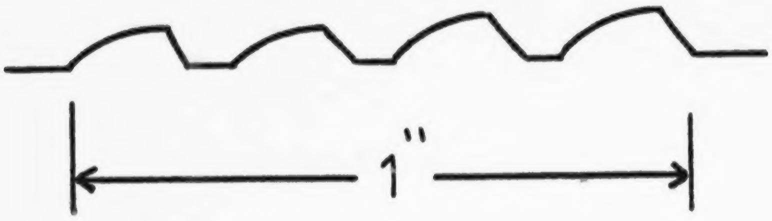

Figure 2. An Enlarged Cross-Section of the Tactile Symbol.

visual symbol for direction, and that the directions implied by smooth and sharp would be towards and away from.

EXPERIMENT 1

Method

Subjects

Thirty recipients of recorded textbooks for the blind served as *S*s. Five of these had completed grammar school or high school only, 15 were college students or graduates, and 10 held advanced degrees, or were working toward them. Their mean age was 31.1 yrs (*SD* = 14.4); 18 were men and 12 were women. Eleven were recently blinded whereas 19 were congenitally blind. Twenty-two had some knowledge of braille (most read Grade 2 braille), and 15 *S*s had some experience using raised line diagrams. Of the 30 *S*s, 15 had seen visual arrows through partial vision or previous vision, and 10 *S*s had experience with these presented in a tactile form. Twenty of the *S*s were totally blind; 10 were legally blind (20/200 vision or less).

Materials

All tactile materials were first produced on thin aluminum sheets, 7 in. by 7 in. by 0.005 in., -0 temper. These were then reproduced on 7 in. by 7 in. by 0.0042 in. *Brailon* sheets, using the Thermoform process. (*Brailon* is a calendered semirigid vinyl.)

A test booklet was constructed of these copies. Sixteen simple directional relationships were each produced in two "modes" - tactile (T) and visual (V). The T symbol was made with the tool shown in Figure 1, whereas the V symbol was produced with a Howe Press fine tracing wheel, which produces a closely dotted line. The maximum rise off the surface of the *Brailon* was 0.024 in. in the case of the T symbol, and 0.021 in. in the case of the V symbol. The arrows were the same length in both modes, and ranged from 1.5 in. to 6 in. in length, depending upon the relationship

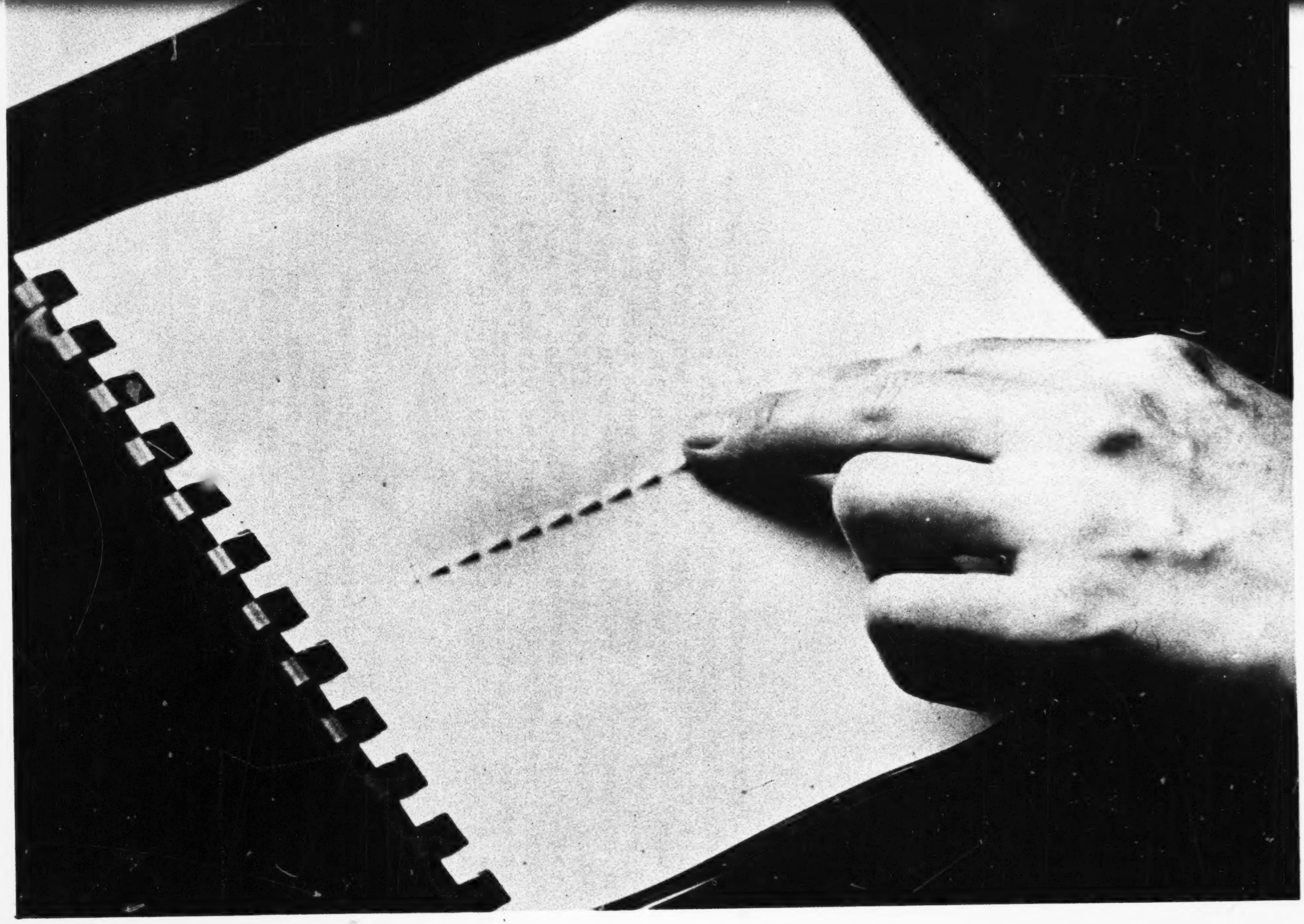

Figure 3. Scanning the Tactile Symbol Produced on Brailon.

shown. In the V symbol the arrowhead consisted of lines 0.25 in. in length, set at 45 degree angles to the shaft of the arrow. The booklet contained the following directional relationships: (1) toward the right; (2) toward the left; (3) toward the top; (4) toward the bottom; (5) toward the upper right corner; (6) toward the lower left corner; (7) toward the lower left corner; (8) toward the upper left corner; (9) perpendicular, toward a vertical line; (10) through a raised textured area; (11) into a raised textured area; (12) out of a raised textured area; (13) clockwise, in an approximate circle; (14) counter-clockwise; (15) parallel vertical (two lines) in the same direction; and (16) parallel vertical (two lines) in opposite directions.

Procedure

Three different orders of presentation were used, each having no more than three diagrams of each mode in succession, being otherwise random. Whether the T or V mode appeared first in an order was counterbalanced. Ten *S*s received each order. Each *S* received all items, yielding a repeated measures design.

The *S*s were tested individually in their homes or in an office at Recording for the Blind. They used no more than two fingers of their preferred hand, and were instructed as follows.

Level 1

"Trace the raised material on the page back-and-forth, and tell me if it means anything to you. If so, what?" After five successive negative responses, *E* went on to the next level.

Level 2

"Trace the raised material on the page back-and-forth, and tell me if there seems to be anything there pertaining to direction. If so, which direction, using up, down, right, and left as reference points? In addition to direction, how does the direction relate to the lines or areas depicted?" (Same criterion for going on as above.)

Level 3

"Tace the raised material on the page back-and-forth, and note that it feels different, depending on which way you trace. Does the line seem to point in one direction or the other? Which? Tell me direction and/or relation to any other lines or areas." (Same criterion for going on as above.)

Level 4

"This is a directional line (or arrow, if it is). When it feels rough or sharp, which direction is it pointing? The opposite direction. Feel these directional lines (or arrows) and tell me where they are pointing...up, down, right, left, etc., and their relations to other lines or textured areas on the sheet."

The *E* used a stopwatch calibrated in 0.01 min to record the time required by *S* to begin a reply to the question posed. Also recorded were: *S*s' descriptions of figures, level of instruction required to grasp the diagrams' meanings, correct or incorrect responses, and preference for T or V mode. Errors were not corrected, nor were correct responses acknowledged during the testing. After the tasks were completed, biographical data were collected. Following this, *S*s participated in a simple line discrimination task.

Results

Errors

Few errors were made on the tasks. Only 26 out of 480 possible errors occurred in the V mode (5.3 percent), whereas 40 out of 480 possible errors occurred in the T mode (8.3 percent). A z test revealed a nonsignificant difference between the modes in proportional errors, ($z = 0.13$, $p > 0.10$). Most errors occurred on diagrams 10 and 13, and in the T mode. Errors appeared evenly distributed in the V mode.

Response Time

An analysis of variance for repeated measures was performed on the time data. Table 1 shows the Overall Treatments, Orders, Relationships (diagrams), the Mode x Relationships interaction, and the Orders x Relationships interaction were all statistically significant.

The 16 diagrammatic relationships proved the most important source of time variance. Table 2 shows the means and *SD*s.

Mode Preference

The results of the mode preference question are presented in Table 3. When subjected to χ^2 analysis, excluding the "no preference" responses, it was found that the preference for the T mode significantly exceeded that for the V mode ($\chi^2 = 14.3$, $p < 0.001$, 1 *df*). Further analyses of the preference data were then attempted, but even the apparently largest difference proved nonsignificant. Neither a congenital vs. recent blindness classification, nor a legally vs. totally blind classification proved significant ($\chi^2 = 0.79$, $p > 0.10$, 1 *df*; $\chi^2 = 0.13$, $p > 0.10$, 1 *df*). Thus the biographical factors bore no apparent relationship to the overwhelming preference for the T mode (24 *S*s preferred the T mode, 4 preferred the V mode).

Table 1

Analysis of Variance: Response Time Data

Source	*MS*	*df*	*F*
Overall Treatments	327	95	5.27**
Error	62	865	
Mode (T-V)	204.6	1	3.30
Orders	414.4	2	6.68**
Relationships (Diagrams)	1220.2	15	19.68***
Interactions			
Mode x Orders	142.6	2	2.3
Mode x Relationships	396.1	15	6.4**
Orders x Relationships	102.7	30	1.66*
Mode x Orders x Relationships	80.9	30	1.31

* $p <.05$

** $p <.001$

*** $p <.0001$

Level of Instruction

Level 4 (maximum information) was the most frequent level required for proper interpretation of the diagrams. Five *S*s were able to comprehend thd directional information at Levels 2 and 3, but no *S*s were able to interpret the diagrams at Level 1 - with either symbol. The exception to general comprehension was awareness of the direction implied by the T symbol (but not the V symbol), which was apparent to *S*s without their being so instructed.

Discrimination of Tactile Quality

All *S*s were able to detect that there was a difference in the

Table 2

Means and *SD*s for Diagrams in T and V Modes

(Response Time)

Diagram		1	2	3	4	5	6	7	8
$\bar{X}$	T	10.0	11.6	7.9	9.8	10.8	8.5	6.8	14.5
$\bar{X}$	V	6.5	11.0	9.7	9.8	7.8	14.5	9.4	8.5
SD	T	4.9	10.0	3.2	6.9	4.6	4.6	2.5	8.0
SD	V	2.6	6.1	5.9	9.3	4.1	11.9	4.3	3.4

Diagram		9	10	11	12	13	14	15	16
$\bar{X}$	T	13.5	22.8	11.2	14.8	13.1	14.5	9.9	14.2
$\bar{X}$	V	19.9	26.8	26.2	11.2	15.7	12.3	7.8	10.3
SD	T	9.3	16.0	5.9	10.3	7.1	15.9	6.7	9.2
SD	V	10.9	18.0	14.4	5.7	9.3	2.2	3.8	5.4

Table 3

Mode Preferences for Directional Symbols

	Preferred T	Preferred V	No Preference
Congenital	13	4	0
Recent	11	0	2
Totals	24	4	2

"feel" of the T symbol when scanned in different directions. Of the 30 *S*s, 29 also indicated that the smooth quality meant "toward" and the sharp scan meant "away from," once they were asked that specific question. The one *S* not saying so was unable to say which tactile quality went with which direction, rather than asserting the opposite.

Discrimination Index and Response Time

The relationship between errors in the line discrimination task and median response time on the directional diagrams was explored using a Spearman rank-order correlation coefficient. This statistic was chosen after a scattergram indicated an unusually shaped distribution. The resulting $\rho = 0.14$, which was not significant ($p > 0.10$, $N = 30$).

Discussion

The general hypothesis stated earlier led to several predictions:

1. that the difference in tactile quality between T and V symbols would be detected by blind *S*s;

2. that the T symbol would be more efficient and meaningful than the V symbol;

3. that the smooth scan would imply towards, and the sharp scan would imply away from.

The first and third predictions were fully confirmed, but the second was only partly confirmed.

Since *S*s easily detected the sharp-smooth difference in the feel of the T symbol, it is evident that the potentially informative stimuli can be picked up by the tactile system, and used in apprehending directional relationships. However, the fact that a good deal of instructional information was usually required for *S*s to apprehend the directional nature of the symbol implies that directionality is not immediately suggested, but easily learned. Once the directional nature of the symbol was made explicit, smoothness was almost always linked with toward, and vice versa. Whatever learning occurred was a short term process. This combined with the much greater preference for the T symbol leads to two possible likely explanations. The first - which is more in line with the hypothesis and predictions stated earlier - is that the T symbol provides stimuli compatible or "in correspondence" with their referents, and is thus easily learned and utilized by the tactile perceiver. Such correspondence is well supported by the agreement as to directions implied by the symbol. An alternative explanation might be that the confirming data were consequences of the *novelty* of the T symbol relative to the V symbol; such novelty lending distinctiveness, attention, and preference to the T symbol. Note that 15 *S*s had prior experience with visual arrows, and 10 had prior experience with tactually presented conventional arrows. There is also the possibility that *S*s realized *E* had a new material made especially for them, producing a "Hawthorne effect."

The significance of Orders, and the Orders x Relationships interaction has consequences bearing on further research with similar materials, but aside from these cautions, has little further bearing on the practical and theoretical issues involved.

The analysis of variance showed no significant difference in response time for the T and V modes, although in 8 cases the V symbol provided shorter response latencies, and in 7 cases the T symbol did so (one tie). This finding not only fails to confirm the prediction regarding the comparative efficiency of the two symbols, but tends nonsignificantly in the opposite direction. The same is true of the relative number of errors; there was a nonsignificant tendency for the V symbol to be more efficient. Several lines of evidence lend themselves to a qualification of the main hypothesis, rather than a simple rejection of the efficiency aspect of it.

Since few errors were made overall, one might suppose that the difficulty level of most of the relationships was very low. Also, the significance of the Relationships variable implies that they were not of uniform difficulty. Furthermore, since the Mode x Relationships interaction was significant, one is led to the possibility that the T and V symbols *do* have differential efficiency effects, but only when the difficulty level of the diagrammatic relationships is sufficiently high. A further examination of Table 2 will reveal that it was the apparently "simpler" relationships (1 through 8) which showed small differences between the modes, while the apparently more complex relationships (9 through 16) frequently produced much shorter response latencies for the T symbol. The *SD*s for Diagrams 9 through 16 tended to be larger than for the earlier diagrams, implying they were more difficult, rather than that *S*s were simply learning to use the directional information, or simply "learning the task." Such an interpretation leads to qualification of the main hypothesis: when the diagrammatic information presented is relatively simple, little if any gain is achieved (re. efficiency) by the use of the T symbol; but as the complexity of the diagram increases, the T symbol becomes relatively more efficient, leading to shorter response latencies for the T symbol. A possible reason for this is that as diagram complexity increases, the details of the diagram are more likely to become confused with the essential features of the V symbol (the arrowhead), but not with the distinct structure of the T symbol.

In order to collect more evidence regarding the reliability of the findings of the present study, and to check on the tenability of the "complexity hypothesis," a further study was carried out.

EXPERIMENT 2

The general hypothesis stated in Experiment 1 appears partly confirmed, but there is no direct support for the contention of superior efficiency of the T symbol as compared with the V symbol. A qualification of the hypothesis appears called for, based on the notion of "tactile noise" increasing more rapidly for the V symbol than for the T symbol as diagram complexity increases.

Method

Subjects

Thirty-two blind high school students ranging in age from 15 to 20 yrs served as *S*s. Half were boys and half were girls. They were selected from and tested at The New York Institute for the Education of the Blind, and The Perkins School for the Blind. All *S*s were legally blind, the majority having light perception only, or no vision. All read braille, using it extensively in their school work, and all but two *S*s had experience using raised line diagrams. The *S*s' IQs were provided by the schools, and had been obtained with Wechsler verbal scales or modified Stanford Binet tests. The IQs ranged from average (97) to superior (146), the mean being 113.9, indicating a higher than average group. Participation in the study was voluntary.

Materials

Eight diagrams and one "mobility map" were each produced in both T and V forms, on the same materials described in Experiment 1, with the exception of the map. The latter was constructed on a heavy cardboard base 7 in. by 8.5 in., upon which were glued 7 wooden blocks of varying shape and size, measuring about 1 in. in diameter and 3/4 in. in thickness. The blocks were patterned asymmetrically on the cardboard, and a winding path 3/8 in. wide containing either T or V symbols (on *Brailon*) led from a start to a finish point. Two radiating paths having T or V symbols pointing *toward* the main path provided "wrong turns" to be avoided by the *S*s in tracing the path.

The diagrams were constructed so as to be somewhat more complex (by inspection) than those used in the first study. The content of the diagrams will be apparent from the instructions provided for each. To rule out confusion between the V symbol and other details of the diagrams due to similarity of lines composing the diagrams and the structure of the V symbol, and thus to determine whether the specific structure of the T symbol would lead to better performance, or whether it was simply contrast between symbol lines and diagram lines, the nondirectional contents of the diagrams were produced in *solid* raised lines. These had a rise of 0.036 in. off the *Brailon* surface. In this study then, the V symbol was produced as a sharp dotted line, having equal or greater contrast to diagrammatic content than the T symbol. Such was not the case in the previous experiment.

Procedure

A sample of either the T or V symbol was placed at the start of each test booklet to familiarize *S* with it prior to the inspection of diagrams. The *S*s were randomly assigned to groups receiving all T or all V symbols. This procedure was desirable in view of the significant Mode x Relationships interaction found in Experiment 1. Only one order of presentation was used, to permit T vs. V comparisons with order effect held constant. Since the Mode x Orders interaction was *not* significant in Experiment 1, the procedure appeared justified.

Instructions were used to familiarize *S*s with the symbol to appear in the remainder of the diagrams, and specific instructions were also given prior to the inspection of each diagram.

Familiarization Instructions

> "This booklet contains a number of raised line diagrams, each of which contains information pertaining to direction. In each diagram there is one or more of these arrows." (*S* was shown the sample symbol.) "The way to use these is to run your fingers back-and-forth along the arrow. (V alternative: At one end you will find an arrowhead. This points in the direction of movement...understand?) (T alternative: Note that this line feels smoother in one direction, and sharper in the other direction. The smooth way indicates the direction of movement ...understand?)"

Specific Instructions for Each Diagram

1. "This diagram shows an automobile. An arrow - like the one you just felt - shows the direction the car is *going*, toward the left or toward the right. In which direction is it going? Touch it now."

2. "This diagram shows a cross-section of an airplane wing, with arrows showing how the air *flows around it*. Does the air flow from right to left, or left to right in this diagram? Touch

it now."

3. "This diagram shows three directions of movement from one point. Two are on the outside, and one is between the other two. In the diagram, is the one in between *going toward* the upper right-hand corner, or toward the lower left-hand corner? Touch it now."

4. "This diagram shows a set of three gears, each one connected to a shaft which is turned by the gear. This is a diagram showing the gears and shafts from the side, so all you can feel of the gears are the edges of their teeth. On each of the three shafts there is an arrow showing you in which direction the shaft is turning. Inspect the diagram, and show me with this pencil in your other hand which way the shafts are turning, starting with the one on the left, and going to the ones further to the right. Touch it now."

5. "This diagram shows a large textured area in the middle of the page, and smaller particles around it. Are the particles being *thrown off* from the large square patch, or are they *converging on* it? Touch it now."

6. "This diagram shows three little figures: a three-dot triangle, a small circle, a large square. Arrows show in which directions they are *going*. In which directions (toward the top, etc.) are they moving? Touch it now."

7. "This diagram shows a large textured area, and an arrow intended to show the path of an object. Tell me whether you think the object: (a) is *about to go into* the large area? (b) *has already gone into* the large area? (c) is *about to go out of* the large area? (d) *has already gone out of* the large area? Touch it now."

8. "This diagram shows three little pairs of figures, two of each of three kinds. Arrows show whether in each pair the figures are *heading toward or away from* each other. The figures are a large rough-surfaced circle, a textured heart-shaped figure, and a square within a square. With each pair of similar figures, indicate whether they would or would not hit each other if they continued moving. Touch it now."

9. (Map) "Let us assume that Mr. Jones reaches the bus station near his home. The diagram traces with arrows the *path* to his home, which feels like this." (*S* was shown the triangular "home.") "Follow the path as quickly as possible to Mr. Jones' house. There are alleys leading off the main path which are misleading, so be careful of them. Touch it now."

Questionaire

After completing the above tasks, *S*s were asked several questions, and biographical data were then collected.

Question 1

"How would you rate these arrow diagrams - in general?"

a. very easy to understand
b. fairly easy to understand
c. fairly difficulty to understand
d. very difficult to understand

Question 2

"How do you like the arrows themselves?"

a. very much
b. OK
c. not very much
d. dislike them

Results

Errors

As in Experiment 1, few errors were made relative to the number of possible errors. However, a greater number and percentage of errors were made in this study. Of 224 possible errors in each mode (excluding the map problem), 60 errors (27 percent) occurred in the V mode, as compared to 36 errors (16 percent) in the T mode. This percentage difference was not found significant when tested with a z test ($z = 0.245$, $p > 0.10$). Although the difference favored the T mode in this study, the difference was not significant.

Since Diagram 4 produced an inordinate number of errors, further analyses were performed separately on the three-gear problem for both modes. As Table 4 indicates, none of these approached significance.

Response Time

The means and *SD*s for decision times on the main diagrams and their subtasks are shown in Table 5. As the table indicates, the diagrams again differed considerably in difficulty, but since the means were generally higher than those in Experiment 1, the assumption that they were more difficult (complex) than the diagrams of the first study is supported.

Since the focal point of this study was the comparison of the independent T and V groups, and since Relationships proved a highly significant variable in the last experiment, a series of t tests was performed, adjusting significance levels to take into account the multiple comparisons of the analyses. Table 6 shows the re-

Table 4

Chi Square Analyses of Right and Wrong Responses to Gear-Shaft Problems

	Left Gear		Middle Gear		Right Gear	
	T	V	T	V	T	V
Right	7	8	5	8	8	6
Wrong	9	8	11	8	8	10
	$\chi^2 = .12$		$\chi^2 = .58$		$\chi^2 = .51$	

sults of these tests. Six of the 15 tasks show significant differences between the two modes. In all of the significant cases, the T mode provided shorter decision times than did the V mode. Of the remaining cases, six means were in the same direction as the significant cases, while three favored the V mode, although not significantly.

Diagram 4 (gears) yielded results peculiarly its own. Since the three subtasks were functionally related, analyses of variance were performed on each mode to determine whether a single representative measure could be used for this diagram. The results of these analyses are shown in Table 7. Since both analyses were significant, no single measure could be used. In each case the left gear shaft (the first one *S*s inspected) required longest decision times. However *t* tests between the mean latencies for each shaft in each mode were not significant (all *t* values being < 0.90, $p > 0.10$). This would indicate that it is the gear diagram parts and not the symbol which results in differing latencies.

Since some previous investigators (e.g., Morris and Nolan, 1961 [12]) have found tactile discrimination scores to be related to IQ, the mean latencies of *S*s in this study were correlated with IQ scores. The results indicated a substantial and significant negative relationship between these variables ($\rho = -0.50$, $p < 0.01$).

Questionnaire

The results of the two questions asked are presented in Table 8,

Table 5

Means and *SD*s on Diagrams and Sub-Tasks in
T and V Modes
(Response Times)

Diagram		1	2	3	4(1)	4(M)	4(R)	5	6(Tr)	6(Cir)	6(Sq)	7	8(Cir)	8(sq)	8(hrt)	9(Map)
$\bar{X}$	T	22.6	15.5	11.9	15.9	7.5	10.5	25.2	6.4	7.3	5.2	17.9	32.1	22.5	11.9	38.9
$\bar{X}$	V	19.9	17.6	20.8	20.0	7.1	10.4	37.5	12.0	13.5	10.7	23.1	23.1	28.5	16.2	60.8
SD	T	14.7	9.4	7.1	15.1	4.4	7.4	26.1	4.3	5.9	3.3	12.2	18.3	17.6	3.8	31.0
SD	V	11.6	11.6	10.9	9.7	3.3	6.8	23.6	6.5	8.2	10.4	9.6	10.7	15.8	4.0	28.2

inspection of which shows that most *S*s judged the tasks to be easy, with no evidence of a substantial difference between T and V groups. However, the preference question (2) produced more favorable ratings for the T symbol than for the V symbol. An attempt was made to test the significance of differences in favorable and unfavorable responses to T and V symbols by assigning half the neutral ("OK" category) responses to each of the bipolar classification of like-dislike, in both modes. After this manipulation a χ^2 analysis showed the difference to be of borderline significance ($\chi^2 = 3.64$, $p < 0.10$, > 0.05, 1 *df*). Several *S*s who received the T booklet, and who had previously used V symbols volunteered that they greatly preferred the T symbol.

Discussion

The results provide confirmatory evidence that the T symbol is more effective than the V symbol as diagram complexity increases above some minimum level. Whereas the previous study indicated that in

Table 6

Results of t Tests on Response Time Means for Diagrams and Sub-Tasks in T and V Modes

Diagram	t	Diagram	t
1	1.22	6(Tri)	4.66**
2	1.23	6(Cir)	4.40**
3	4.22**	6(Sq)	2.20
4(1)	.90	7	2.74
4(M)	.32	8(Cir)	2.40
4(R)	.03	8(Sq)	3.11*
5	4.48 **	8(Hrt)	1.13
		9(Map)	6.77***

* $p < .05$

** $p < .01$

*** $p < .001$

most simple diagrams the V symbol was equally efficient (if not equally well liked), in this study response latencies indicated superior efficiency of the T symbol in many cases, and tendencies in that direction in other cases, although the error measure provided somewhat equivocal results. The results of the two studies taken together imply an interaction between type of symbol used and diagram complexity, bearing on decision time.

An alternative to the hypothesis that diagram complexity interacts with symbol type, the relative efficiency of the T symbol increasing as diagram complexity increases, is that the diagrams

Table 7

Analyses of Variance on Diagram 4 in T and V Modes (Response Time)

T Mode

Source	MS	df	F
Treatments	594.65	2	8.5*
Error	69.8	45	

V Mode

Source	MS	df	F
Treatments	668.0	2	12.5*
Error	53.5	45	

* $p < .001$

in Experiment 2 were no more complex than those in Experiment 1, but *S*s in the second study were lower in ability. This alternative seems doubtful in view of the generally high intelligence of the *S*s in Experiment 2, and their tactile efficiency as demonstrated by their proficiency in using braille. The *S*s in the second study rated the tasks as relatively easy, indicating that their conceptual abilities were adequate for interpretation of spatial diagrams. Yet, they took longer and made more errors than *S*s in Experiment 1. This points to the complexity hypothesis as the most tenable explanation of the results of both studies. Weiner (1963) found a similar phenomenon, in that good and poor braille readers did equally well on simple tactual tasks, but good braille readers did significantly better on more complex tactual tasks. These results were interpreted as indicative of superior tactual skills and neural sensitivity becoming evident on the more complex tasks (19). Although this conclusion was not warranted, since the two groups (good and poor readers) also differed significantly in IQ and other factors which could have easily accounted for the differences found, the results of the present studies do support the

Table 8

Number of Responses to Questionnaire Items in T and V Modes

Difficulty Question	T	V
a. very easy	10	5
b. fairly easy	5	10
c. fairly difficult	0	1
d. very difficult	1	0
Preference Question		
a. like very much	11	4
b. OK	5	9
c. not very much	0	0
d. dislike	0	3

notion of an interaction between tactual task complexity and other tactile information in a display bearing on performance. The source of performance differences on simple and complex tactual tasks is still open to question regarding whether the differences are due to cognitive differences, tactual differences, or both.

The importance of diagrammatic content in qualifying the relative effectiveness of symbols was attested to by the results. As suggested in Experiment 1, the interpretation of *all* diagrams is probably not benefited substantially by replacing the V symbol with the T symbol. The more complex diagrams appear to benefit most, and none appear harmed by the T symbol's inclusion. It thus appears that general usage of the new tactile symbol for direction would result in increased efficiency of apprehension, with some diagrammatic contents benefitting more than others. The "gear" type of diagram apparently requires further development before it can be clearly apprehended in either mode.

The significant difference in performance on the "mobility map" in favor of the T mode provides great promise for use of the T symbol. The need for well-designed symbols for tactile maps has recently received specific comment (18), as has the need for an efficient directional symbol (21). It appears that the specially designed T symbol, or some form of it might provide one answer for this need, especially with a brief training period regarding its use. (A new tool providing smaller, more closely-spaced units has been developed since these studies were performed.)

The results of the present study imply that as intelligence increases, response time to tactile diagrams decreases. This finding supports similar data of Morris and Nolan (12), while indicating that contrary findings of *no* relationship between tactual performance and IQ (3, 19) may have been due to their use of time-*independent* performance scores. There is also the practical implication of this finding, that in the education of blind persons of average and lower intelligence, more time is required for them to inspect and apprehend tactile diagrams. Whether the relationship between IQ and response time is due to spatial characteristics of the diagrams, instructional difficulties, or temporal components in intelligence measures, or other factors, is not known.

The findings of both studies suggest that the more complex a diagram is, the more it is likely to benefit from the use of materials (e.g., symbols) whose structure provides informative stimulation. Perhaps the useful role of such symbols is that of supplying redundant stimulus information, which has been found to interact with diagram complexity in affecting tactual performance (17).

Not only did the T symbol's superiority become apparent in the second study where the diagrams were generally more complex, but it appeared that within Experiment 1, the more complex diagrams were similarly affected. The judgment of "more complex" was of course qualitative, and further research manipulating this dimension of stimulation would no doubt benefit from quantification, as has been the case in visual and auditory studies in perception. Since even after further discriminability controls were added, more errors were made and decision time increased, the assumption of greater complexity in the second set of diagrams was supported. But answers to the difficulty question (1) imply that the diagrams were not very far out along a complexity dimension.

Finally, the present study supports the authors' initial contention that consideration of tactile symbols having properties of "S-R compatibility," "physiognomic properties," "informative stimulus structure," or whatever the preferred conceptualization may be, is a promising and important aspect of research on symbolic displays for various modalities. The results suggest that consideration of information provided by symbol structure may pay off in increased efficiency and meaningfulness with a minimum of training. Whether retention of symbol referents - especially under stressful decision-making conditions - is enhanced by such symbol structure, remains an interesting question for further research.

EXPERIMENT 3

Blind persons reply on tactual skills, and usually practice these skills extensively. What is the relevance of these skills to performance with the T and V symbols used in tactile diagrams? If the difference found between the performances provided by the two symbols is due to past tactual experience in the case of blind persons, and visual experience in the case of sighted persons, one might expect sighted *S*s' performance with the T symbol to be inferior to that with the V symbol. If, on the other hand, the reason for the superiority of the T symbol in more complex diagrams is due to providing informative stimuli for the perception of directional information, sighted persons should perform similarly to blind persons relative to the two symbols. The question is then, whether blind persons' developed skills in picking up and utilizing this tactile information are necessary conditions for its usefulness, or whether no special education of the tactile-kinesthetic sensory system is required for such results.

Weiner (1963) has suggested that as tactual task complexity increases, tactual skills become more important in affecting performance than at a lower difficulty (19). On the other hand, it is possible that *cognitive* factors rather than tactual sensitivity factors produce such effects as Weiner's finding that good braille readers exceed poor ones on difficult tactual tasks, but not on simple tactual tasks; and the interaction effects between symbol type and diagram complexity - suggested by the last two studies. If cognitive factors are indeed the most important, one might expect sighted *S*s to exceed blind *S*s in their performance on directional diagrams, assuming sighted *S*s of comparable educational level have superior conceptualization of spatial relations. If tactual sensitivity factors are most important, blind *S*s - with their greater practice in relying on tactile information gathering - should exceed sighted *S*s in their performance on directional diagrams. To investigate these questions, the following study was conducted.

Method

Subjects

The *S*s were 11 undergraduate students selected haphazardly at The City College of New York. All were paid volunteers having normal or corrected vision. Six were men and 5 were women.

Materials

All materials were exactly as in Experiment 1, except that blindfolds were employed to help prevent *S*s from viewing diagrams.

Procedure

The procedure was approximately that employed in Experiment 1. Exceptions included instructions for *S*s to keep their eyes closed and avoid viewing the diagrams, since this would invalidate the study. Also, mode preference data were not collected, nor was a discrimination index employed. Three *S*s received Order 1, and 4 *S*s each received Orders 2 and 3.

Results

Errors

The sighted *S*s made few errors, 7 out of 176 possible errors (3.98 percent) in each mode. These totals were less than those of the blind *S*s in Experiment 1, but roughly comparable.

Response Time

An analysis of variance for repeated measures was performed on the time data. As Table 9 shows, with the exception of the weak Orders x Relationships interaction found in Experiment 1, but not in the present study, the same factors found significant for the blind *S*s were significant for the sighted *S*s. Table 10 shows the means and *SD*s for response times on the various diagrams, in both modes.

Level of Instruction

Of the 11 *S*s, only 3 required Level 4 (maximum information) instructions to comprehend the directional nature of the symbols. Six *S*s required Level 2 and 3 instructions, and 2 operated primarily at Level 1. However, there was a good deal of fluctuation for almost all *S*s. Typically they would be able to interpret some of the early diagrams, but would "get stuck" with the more difficult ones, requiring further instruction. Although this finding was far from conclusive, it did suggest a difference in level of instruction required in the blind and sighted groups.

Discrimination of Tactile Quality

None of the *S*s had any difficulty discriminating the "sharp" scan from the "smooth" scan. Also in line with Experiment 1, *all* *S*s indicated that the smooth direction corresponded to toward, and vice versa.

Comparison of Blind and Sighted *S*s' Performances

T tests were used to compare blind and sighted *S*s' mean response

Table 9

Analysis of Variance: Response Time Data

Source	MS	df	F
Overall Treatments	312.57	95	3.38*
Error			
Mode (T-V)	23.01	1	.25
Orders	1986.97	2	21.51*
Relationships	828.19	15	8.97*
Interactions			
Mode x Orders	59.50	2	.64
Mode x Relationships	434.35	15	4.70*
Orders x Relationships	104.89	30	1.14
Mode x Orders x Relationships	116.53	30	1.26

* $p < .001$

times in the two modes. As Table 11 indicates, blind *S*s (Experment 1) were faster than sighted *S*s in both modes, but only the difference in the T mode reached a significant level ($t = 2.72$, $p < 0.02$), although the difference in the V mode tended in the same direction ($t = 1.31$, $p < 0.05$). The results shown in Table 11 also indicate that it was the large variance with the V symbol - especially in the sighted *S*s - which prevented the mean difference from reaching a significant level.

Discussion

The results of the analysis of variance provide strong support for the notion that variables affecting blind *S*s performances with T and V symbols are not specific to blind persons, but reflect general determining factors. However, two findings suggest that sighted *S*s have less difficulty with diagrammatically presented

Table 10

Means and *SD*s for Diagrams in T and V Modes (Response Time)

Diagram		1	2	3	4	5	6	7	8
$\bar{X}$	T	16.1	17.5	15.5	10.9	26.7	18.9	18.7	14.0
$\bar{X}$	V	11.1	26.4	10.0	8.5	31.8	22.8	10.2	43.4
SD	T	10.7	6.7	8.4	7.7	15.8	7.9	10.5	7.5
SD	V	4.4	15.3	4.7	4.7	17.9	13.7	5.6	25.9

Diagram		9	10	11	12	13	14	15	16
$\bar{X}$	T	16.0	12.0	18.0	17.0	10.3	10.6	13.5	19.9
$\bar{X}$	V	13.5	11.5	17.1	13.1	12.4	11.7	9.1	15.1
SD	T	12.5	6.8	11.8	12.1	5.6	5.9	7.7	10.2
SD	V	6.7	6.6	9.2	5.8	7.4	5.7	4.6	9.9

directional information: the tendency for less information to be necessary for diagram interpretation by sighted *S*s than by blind *S*s, and the fact that sighted *S*s made fewer (nonsignificantly) errors than blind *S*s. An explanation based on higher IQs in the sighted sample cannot be ruled out, however, since this information was unavailable. Still another possibility is that blind *S*s, in getting more instructional information, were able to use their inspection time more efficiently, resulting in shorter latencies; while sighted *S*s used much of their inspection time discovering the nature of the task. This last explanation could also account for sighted *S*s generally longer response times, and greater variance on the response time measure, but still leaves their better error scores unexplained. However, there does seem to be a realistic tendency for many blind persons to ask for maximum instruction in executing a novel task.

The finding that response times were not significantly different in the T and V modes for the sighted *S*s supports the second alternative stated in the introduction to this experiment - that informative stimulation provided by the T symbol's structure

Table 11

Comparison ot Means and *SD*s of Blind and Sighted *S*s in T and V Modes (Response Time)

		T	V
Blind *S*s		$\bar{X}$ = 12.12	$\bar{X}$ = 12.96
N = 30		*SD* = 3.80	*SD* = 6.26
Sighted *S*s		$\bar{X}$ = 15.97	$\bar{X}$ = 16.73
N = 11		*SD* = 4.22	*SD* = 9.70

is the source of its effectiveness when diagram complexity is increased. If blind and sighted *S*s' differential past experiences with tactile and visual perceptual systems respectively had been the source of this difference, one would have expected sighted *S*s to perform significantly better with the V symbol, but such was not the case.

The second issue discussed in the introduction to this experiment was that of cognitive vs. tactual bases for Weiner's (19) findings, and those of Experiments 1 and 2 reported here. Since blind *S*s were significantly faster than sighted *S*s in the T mode, and faster, but not significantly so in the V mode, the tactual sensitivity explanation appears at least partially supported. But from the combined results of our three experiments, it actually appears as if *both* cognitive and tactual factors may be involved. It seems quite plausible that cognitive factors may provide somewhat better accuracy (sighted *S*s made fewer errors than blind *S*s), while tactile-kinesthetic sensitivity may provide somewhat more speed, thus explaining the discrepancy between these measures throughout the present studies, as well as other studies in this area (e.g., Schiff and Isikow, 1966 [17]). In other words, the error measure may load heavily on cognitive factors involving spatial abilities, and the time measure may load heavily on factors involving tactile discrimination and perception. This hypothesis would seem worth following up in future research on tactile perception.

SUMMARY

Several alternatives to the "signal" approach to the development of symbolic referents led to the production of a special tactile symbol providing stimuli specifying directionality. Two experi-

ments compared the results of apprehension of directional relationships in tactile diagrams by blind students, using the special tactile symbol, and a tactile form of the standard visual symbol for direction (arrow). Either symbol worked well in very simple diagrams, but as diagram complexity increased, the special symbol led to significantly shorter response times, and nonsignificantly fewer errors, implying an interaction between symbol type and diagram complexity bearing on response latency. Most *S*s preferred the new symbol. Significant order effects, effects of diagrammatic content, and several interaction effects were also found. Intelligence was negatively related to response time.

A third experiment repeated the first study with sighted students. The pattern of findings closely paralleled those with blind *S*s, suggesting that the results were general findings, rather than specific to blind persons. However, it was also found that sighted *S*s took longer to respond, while making slightly fewer errors than blind *S*s. The results were discussed while considering the possible involvement of cognitive factors and tactile sensitivity factors in tactile diagram apprehension. Implications for tactile graphics for the blind and for the development of symbolic displays were also discussed.

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THE GERMAN SYSTEM OF CONTRACTED BRAILLE: SOME CRITICAL POINTS OF VIEW*

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The use of contracted braille by the blind makes possible not only a rapid reading and writing of braille texts, but also a reduction in the size of braille books by about one-third. Its rules are dictated by the language that is written, and by the characteristic modes of thinking of those who drafted them. German contracted braille therefore reflects, on the one hand, the complicated nature and difficulties of our grammar and spelling; and on the other, German thoroughness and attention to detail. However one becomes involved with contracted German braille, whether writing it, reading it, or even teaching it, one cannot avoid the problems inherent in its creation.

What is most striking at first glance is the immense set of rules. Whereas the German system encompasses about 100 large pages, a similarly thorough English system has sufficient room on about 50 smaller pages, the older French system fits into a brochure of about 30 small pages, and the Swedish system requires only 8 reduced size pages. The extent to which these systems are equivalent will not be discussed here, but one cannot brush off the impression that only a specialist could feel at home in the jungle of rules of German braille, even if one reads letters written by educated people who have used it for years - and sometimes for decades. How small must be the number of those, then, who are able to write German contracted braille according to its rules?

On this point our braille system does not withstand criticism.

Another objection might be concerned with the arrangement and completeness of the system. When German braille, Grade 2, was created, it seemed sufficient to adapt it to a "...pure German language." No provision was made for abbreviating foreign words. As a result, the system began to prove inadequate when scientific literature was transcribed into braille; today it is really hard to understand why, in the early 'twenties, the system was not completed to make room for such abbreviations, for foreign expressions are found not only in scientific texts, but have increasingly entered colloquial language through the influence of policies and technology.

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These two basic criticisms of the German braille system are not the only ones that could be made; indeed, if details were to be considered, the number of objections would be legion. Here, however, I should like to draw attention to a new development which makes the present system a very questionable affair at best. It is that the printing of German braille materials will probably meet with extremely difficult problems when present highly skilled transcribers reach retirement age and must be replaced with new and qualified personnel.

For this reason alone one recent development should be kept in mind, since it offers an exceptionally good opportunity to meet the crisis. This is the automatic transcription of ink print text into braille text. In the United States the first successful tests in automatic transcription have already taken place.

Once a sufficiently large computer is programmed with the set of rules for contraction, an adequately coded normal text is fed to it. The computer translates from ink print coding to contracted braille coding, and its output controls, directly or indirectly (through an intermediate storage like punched paper tape), the braille stereotyper. Using this process, skilled labor therefore becomes dispensable. For input, it is still necessary to transcribe the ink print text on to punched paper tape, but this can be done by any good typist. In the future this, too, might be entrusted to an automatic reading machine. The critical process is the translation of normal (ink print) text into contracted braille text.

It should be very obvious that the technical effort necessary in this connection will increase rapidly with the degree of complexity of the system for contractions in braille. The more involved the braille system is, the more extensive must the computer program be, and the larger the computer system that will be required. In short, the simpler the rules of contracted braille, the cheaper the transcription can be made.

To someone not familiar with recent technology, this development might seem fictional. Nevertheless, the possibility of automatic braille transcription will exist in the near future, and the use which might be made of it in the German-speaking world will depend very definitely upon the system of contractions that the transcribing system will be expected to handle. To put it even more clearly: if we in Germany intend to keep in step with these developments, the reform of the rules for German contracted braille is an inevitable necessity. It is advisable that this be undertaken immediately.

Such revision has been the subject of discussion for decades. For several years a committee for reform has been in existence. After a lengthy discussion of the questions involved, published in the periodical *Marburger Beitrage zum Blindenbildungswesen*, the committee (under the chairmanship of Professor Doctor Strehl) tried to improve the system of contracted braille during the years 1954 to 1957 - but without success. It has been said that the efforts of the committee failed primarily because of the attitude taken towards its work by the VDB (Verband Deutscher Blindenlehrer). Judging from the results obtained, however, the outcome should not be overly regretted, since the good ideas on which the second draft of 1956 was based were considerably watered down in the third draft of 1957.

In the meanwhile the problems of revision have matured further, so much so that the reform of the system of braille contractions can now be regarded as a "must." It is well known that such demands are satisfied eventually, no matter how strongly they are opposed by the few who cling to old fashions. In the near future a small group of experts will have to meet (not as in the 'fifties, when too many cooks were busy at the same pot) to tackle the problem again and a find a solution after considering all the determining factors involved.

The reading matter transcribed so far should not be stripped of its value, however; existing contractions should be changed as little as possible. The list of contractions should be completed, and the set of rules for their use should be changed so that it will no longer challenge the user to simply disregard them, but allow of their mastery with a minimal expenditure for automatic transcription.

Professor Strehl will certainly be ready again to undertake the necessary work, and to advance it through the facilities of the Marburg Blindenstudienanstalt.

Since the system of contractions is taught in the schools for the blind, however, an open-hearted and positive attitude of co-operation on the part of those who teach the blind would be in the best interests of the cause. Let us hope that eventually - after an already too-long delay - it will be possible to solve this problem in a satisfying way!

AUTOMATIC TRANSLATION OF INKPRINT TO BRAILLE BY ELECTRONIC DATA PROCESSING SYSTEMS

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INTRODUCTION

In the May/June 1963 issue of *Der Blindenfreund* Mr. Karl Britz of the Blindenstudienanstalt in Marburg indicated the necessity for changes in German braille Grade 2 (2). Mr. Britz reasons that after these changes automatic translation from inkprint to braille would be possible and in this way the German braille printing houses would be able to cope with the shortage in specialists for braille. Mr. Britz points out that successful experiments in automatic transcription have been made in the U.S.A. (3).

For two years similar experiments have been carried out in Germany at the Department of Applied Mathematics of the University of Hamburg (Institut für Angewandte Mathematik der Universität Hamburg) under the supervision of the senior author (since May 1964 at the University of Münster) and sponsored by the Deutsche Forschungsgemeinschaft (6).

Mr. Mansholt, teacher for the blind in Hannover, and the Hamburger Arbeitskreis Blindenkurzschrift (a group of teachers from the School for the Blind in Hamburg) advised us on the readability of the automatically produced braille.

The first part of this paper describes how the automatic translation is carried out and what problems and difficulties arise in this task. The Hamburger Arbeitskreis Blindenkurzschrift has worked out a proposal to reform German braille Grade 2 to solve these problems and, at the same time, to simplify the shorthand. This proposal is described in the second part of this paper.

AUTOMATIC TRANSLATION FROM INKPRINT TO BRAILLE

The automatic translation from inkprint to braille is carried out in three steps:

1. The inkprint is punched into IBM cards by means of a key-

punch that is operated like a typewriter. This job does not require any knowledge of braille. It is expected that later on automatic readers will take over this job.

2. The IBM cards containing the inkprint are read by an electronic data processing system (computer). The translation of the inkprint to braille is performed within the computer. As the result the computer produces IBM cards containing the coded braille.

3. These IBM cards are used to control an automatic embossing machine that produces metal plates for the braille print.

Such automatic embossing machines have been constructed in the United States by the American Printing House for the Blind (APH) in Louisville, Kentucky in cooperation with IBM. By this automation a considerable amount of money is saved in producing braille (7).

Mr. Zickel of the APH has been kind enough to produce some samples of automatically translated German braille Grade 2 on the automatic embossing machines of the APH.

In Europe there are braille typewriters controlled by teletape available in Eindhoven and Leidschendam in the Netherlands.

The Program

The most important step of the automatic translation program is the change from inkprint to braille within the electronic computer. The other steps involve technical problems only. The speed of the translation, however, depends upon the mechanical equipment: the punching of the cards (speed of the typist) and the embossing of metal plates (12 pages per hour). Translation within the electronic computer is much faster (10 braille pages per minute).

Translation in the computer is controlled by a program that regulates the process exactly. The main difficulties that arise in writing a program are due to the requirements of computers, for to a computer the inkprint is only a sequence of characters (letters, punctuation signs, numbers, blanks) which the computer is able to distinguish and which it reads in the usual way (namely from left to right). In contrast to the human reader, these symbols have no "meaning" to the computer. Automatic translation consequently depends solely on the symbol and the sequence of the inkprint symbols.

One can translate the inkprint letter by letter into braille, so that every inkprint character has a corresponding braille character. This is approximately the case for braille Grade 1. In order to take care of contractions of braille Grade 2 (4) the computer must use a dictionary. Within this dictionary each inkprint symbol and each sequence of inkprint symbols that may be contracted are stored, together with the corresponding braille characters and simple rules concerning their use. During translation the computer compares the beginning of the inkprint to be translated with the sequence of characters in the dictionary and selects the longest sequence from the dictionary that is equal to the beginning of the inkprint text. For this sequence the corresponding braille characters are substituted with reference to the simple rules given in the dictionary. The remainder of the inkprint characters are treated in the same way until all the inkprint has been translated into braille. This method uses only the form of the inkprint; hence it can be carried out by a computer.

Contractions

The use of contractions is restricted by a number of rules (4), which for the most part refer to the meaning of the inkprint. The problems which arise in obeying these rules are treated here according to increasing degree of difficulty. Only some characteristic rules are selected that are typical for those problems.

1. Some of the contractions for syllables and groups of letters may not be used at the beginning or end of a word. The computer recognizes the beginning or end of a word by the fact that the preceding or following character is not a letter. For example, AL: if the following character is "no letter" (that is, at the end of a word), it is translated not by

⠒ but by ⠁⠇

The simple rules mentioned above, which are contained in the dictionary, are rules of this kind.

2. If different contractions could be applied to translate a certain word, priority rules are given which uniquely determine the form of the braille word. For example,

> (LL) and also (AL) are contractions in German braille, and (LL) takes precedence over (AL). The sequence ALL is therefore shortened to A(LL), as in BA(LL) [not B(AL)L].

Since the computer is working through the printed text from the left to the right, one could get the wrong braille translation using the procedure described above. To cope with this, the dictionary is enlarged by including the critical sequence of letters together with their correct braille translation. For example, ALL with the translation [A(LL)].

All the other critical combinations which arise from rules of priority are treated similarly.

The rules quoted so far solely depend upon the form of the inkprint characters. The next and especially the subsequent rules depend on the meaning of the inkprint (4) and therefore much greater difficulties arise in adapting them to automatic processing by machine.

3. As an exception to the rules of priority, BE and GE are always shortened when they are prefixes. For example,

(BE)SETZ(EN) not B(ES)ETZ(EN) (to occupy).

By the rules of priority the sequence BES would be shortened to B(ES). The computer cannot decide whether BE is a prefix or not. This is communicated to the computer by including the critical combinations in which BE is a prefix in the dictionary, with the instruction that BE is to be shortened as a prefix. The critical combinations for BES are BESA, BESCH, BESE, BESI, BESO, BESP, and BEST. Other critical combinations are not possible because of the word structure of the German language. But there are exceptions to these critical combinations in which BE is not a prefix, and which therefore are shortened in another way. For example,

the word 'Besen' is shortened to
B(ES)(EN) not (BE)S(EN) (broom).

These exceptions have to be included in the dictionary, too. The decision as to whether BE is a prefix or not can thus be made by inspecting the form of the inkprint.

While 40 additional letter strings would be sufficient to take care of the priority rules, one would need 120 additional letter strings to make a correct translation of BE and GE and it still may happen that a word is translated incorrectly because one exception has not been included. Our experiments have progressed far enough that this source of mistakes has been nearly excluded.

4. Characters belonging to different parts of a compound word may not be contracted. Therefore the following contractions are forbidden:

HAU(ST)ÜR (door of the house)
BAD(EM)EISTER (baths attendant).

Since the computer does not understand the meaning of the words it contracts, ST, EM or other such letter sequences would be contracted, even if the contraction is forbidden in writing braille. This can be avoided by including critical compound words with their correct braille transcription in the dictionary. Since one can go on and on in forming compound words in German, the dictionary would be too large to fit into the memory of the computer if all such words would be included. On the other hand, such compound words are not very frequent. If the contraction ⠎ is used only for the German letter β and no longer for SS, a lot of mistakes are thereby excluded; on 30 braille pages we found only one compound word in which such an incorrect contraction occurred. The readability of a text is therefore hardly compromised, and it would seem not to pay to include some 1000 additional letter strings in the dictionary because of one word in 30 pages.

5. A large number of restrictions applies to word contractions, i.e., contractions which may only be applied to the abbreviation of whole words alone or parts of compound words. The computer is able to distinguish between one-character word contractions, two-character word contractions, prefixes, and suffixes by means of the form of inkprint and of braille, and thus to insert the correct "separation" characters between the components of a compound word. This applies, however, only with some restrictions, as we will see later; we have pointed this out already with respect to the prefixes BE and GE. To distinguish between compound words which consist of two and of more than two components requires a double reading of these compound words: first, they must be read to get the number of the components, and second, they must be read to obtain the braille transcription.

It has already been pointed out that the computer does not sense the meaning of the text, but translates only according to formal letter strings. Thus, the preposition AUF would always be translated as a one-character word contraction, and also if it is part of the stem, as in

'laufen'	(to run)
'kaufen'	(to buy)
'schnaufen'	(to snort).

The same applies to UND in

'Hund'	(dog)
'Stunde'	(hour)

and other examples. A text containing such contractions seems to disturb the aesthetics of the language if not the readability of it.

The simplest way to overcome this difficulty is to use one-character word contractions only if they stand separately, and to transliterate them letter by letter if they are used in compound words. (The dictionary would become too voluminous if one tried to include all exceptions.) One should only admit inflexion of those contractions, for instance with

'hätte' (subj. had)
'welcher' (which).

In doing so, German Grade 2 braille would be simplified because the rules for using the one-form word contractions within a compound word are very complicated. This twin advantage should be worth the cost of extending the braille text by about 0.4 percent. The few exceptions which also occur with the two-form word contractions can be handled by means of the dictionary, which at present has about 600 entries (see below).

All the difficulties described so far could be overcome by including every word of the German language with its correct transliteration into a huge dictionary. This method, however, cannot be applied due to the limited capacity of computer memories. Besides, in a living language, new words are constantly being generated, and hence new sources for errors would have to be removed constantly.

6. For quite a few words not even the method last quoted would work if only the form of the word itself is considered. For instance, ODER (or) may be a conjunction which must be contracted. It may also mean the river 'Oder,' in which case it has to be transliterated letter by letter. In such cases the contraction should be "legalized." The readability is not reduced thereby.

7. At the end of each line a lot of space is lost because the computer does not separate syllables. The loss may mount as high as 5 percent, due to the frequency of long words in German. Experiments are now being carried out by IBM to perform automatic separation of syllables; automatic braille production programs may later on benefit from these experiments.

THE PROPOSAL TO REFORM GERMAN BRAILLE GRADE 2

The proposal of the Hamburger Arbeitskreis Blindenkurzschrift group to solve the problems sketched above and to unify the German braille Grade 2 is based upon the following principles.

The Problem

The changes are bound to such a small framework that

1. the available braille literature and the available metal plates are not devaluated (that is, the old braille Grade 2

should remain readable for every one who knows the new code);

2. older readers can read the new code without great trouble;

3. the new braille Grade 2 is readable wherever the German language is spoken, even if the changes are not accepted everywhere.

One has to take care that

1. braille Grade 2 as the general written communication of the blind remains uniquely determined in each of its words and suffixes (for instance, they are not understood only from the context, as happens in ordinary inkprint shorthand);

2. the readability of Grade 2 braille is not reduced by these changes (characters and character sequences difficult to read should be avoided);

3. the changes simplify the complicated rules of German Grade 2 braille;

4. the volume of braille books does not increase significantly.

Proposed Changes

The proposal of Hamburg suggests the following changes:

1. The character ⠮ is only used for the letter ß :

SS is written letter for letter (see above).

The characters for IG and LICH are used like contractions for syllables and letter groups. They are written letter for letter at the beginning of the word because they are hard to read there or can be mistaken for other characters.

2. The characters for the word contractions, which may be changed by inflexion, mean only the stem of the word. Endings have to be added in any case (and also with the infinitive). That changes the meaning of the following contractions

a) one character word contractions

Ä = HÄTT (had, subj.)
H = HATT (had)
(EL) = WELCH (which)

b) two character word contractions

BB = BLEIB (remain)
BD = BEID (both)
BG = BRING (bring)
FG = FOLG (follow)
FH = FÜHR (lead)
FR = FRAG (ask)
JD = JED (every)
K(MM) = KOMM (come)
KT = KONNT (could)
LB = LEB (live)
NH = NEHM (take)
(SCH)B = SCHREIB (write)
S(CH) = SOLCH (such)
WK = WIRK (operate, produce)
Wß = WISS, WIß (know)

c) comma word contractions (auxiliaries)

,D = DÜRF (may)
,H = HAB (have)
,K = KÖNN (can)
,L = LASS, LAß (let)
,M = MÜSS, MÜß (must)
,Ö = MÖG (like)
,O = WOLL (will)
,S = SOLL (shall)
,W = WERD (become; shall, will in future).

The contraction S(LL) for SOLL is no longer to be used.

d) (GE) = GEWESEN and (GE)W = GEWORDEN are used like word stems if endings have to be added.

e) Examples of the above changes:

HE = HATTE
(SCH)B(EN) = SCHREIBEN
,S(EN) = SOLLEN
(GE)(EN) = GEWESENEN
(GE)W(EN) = GEWORDENEN.

3. Word contraction in compound words

a) one-character word contractions are written letter for letter in compound words, using the contractions for syllables and letter sequences

b) two-character word contractions are separated by a hyphen (⠤) from preceding or following parts of the word. The hyphen is omitted before or after a comma contraction; if the two-character word contraction is preceded by one of the eight prefixes AN, BE, EIN, ER, GE, IN, UN, or VER; if so, the hyphen then precedes the prefix.

4. Suffixes

a) In the current rules UNG is only contracted as a suffix not as part of the word stem. But, the computer cannot distinguish whether UNG is a suffix or part of the stem and would contract UNG in every case, as for example in

DU = DUNG (dung)
JU = JUNG (young)
HU(ER) = HUNGER (hunger).

Such contracted words are either not unique or are not difficult to read. It is therefore suggested that UNG will not be contracted at all.

b) The plural of the shortened suffixes HEIT, KEIT, SCHAFT is formed by adding EN instead of N.

c)
M = MAL
MS = MALS
F = FALLS
W = WAERTS

are contracted always, and not only when they are suffixes standing at the end of a word and not alone. For example,

D(EN)KM = DENKMAL (monument).

All other rules of current braille Grade 2 remain unaltered.

Although these changes enlarge a word by one or two braille characters from time to time, the total number of characters in a text will, on the average, only increase by two-thirds of 1.0 percent (that is by 1 page in each 150 pages). This increase seems worthwhile for the simplifications obtained.

Tests with blind students and adults indicate that the braille Grade 2 code, with these changes, is readable without any new learning. Readers declared that the changes did not disturb them.

It would appear that the new code complies with the initial principles.

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THE ABILITY STRUCTURE OF THE BLIND AND THE DEAF: FINAL REPORT*

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INTRODUCTION

This final report consists of two parts, the studies on the blind, and the studies on the deaf, respectively. In the case of each separate project, publication or research report, an account will be given of the problems, the subjects, the statistical treatment, the central results, and the problems to be dealt with in continuation studies. The tests and other measuring instruments are described in detail in the relevant publications and reports.

PART I: STUDIES ON THE BLIND

On the Dependence of the Ability Structure upon Vision

The study was concerned with the following ability traits: reasoning; verbal comprehension; numerical ability; spatial ability; memory; dexterity; finger dexterity; tactual discrimination; kinesthetic mastery of hand positions; and auditory sensitivity.

Two groups of problems were subjected to investigation. In Part I of the study, an attempt was made to discover how the above ability traits depend on the degree of blindness, the age at the onset of blindness, the duration of blindness, and the person's chronological age. The problems dealt with in Part II were the following.

What is the general degree of differentiation of the ability structure of the blind? Are the factors for the blind identifiable with factors generally obtained with the seeing? And: Are they explicable in terms of the same psychic functions? Is it demonstrable that certain ability traits play a more central part in the total variance of the test battery with the blind than with the seeing? Can the absence of vision lead to differentiation of some new function from the rest of the ability structure? How does the factor structure of the congenitally blind - which is the group of the greatest theoretical interest - differ from the factor structures of the adventitiously blind, the partially sighted and the seeing? Particular attention was devoted to the interrelationships of spatial tasks to be performed visually and analogous tasks to be performed tactually.

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* This is a report on research carried out at the Institute of Occupational Health. The work was started in 1958, and it was supported by grant M-3593 from the National Institutes of Health, Public Health Service, U.S.A. This material, together with the papers listed under References, constitutes the final report on research carried out during the grant period (July 1, 1960 through May 31, 1965).

The group of subjects consisted of 114 totally blind, 114 partially sighted, and [illegible] seeing persons. Use was made of varied breakdowns according to the degree of blindness, the age at the onset of blindness, the duration of blindness, and the subjects' chronological age and sex.

The methods resorted to in Part I were comparative analysis of group means and the analysis of variance. Part II was factor analytical throughout. Use was made of Thurstone's centroid method and, to some extent, of the principal axis method: graphical rotations into orthogonal axes and cosine-rotations into oblique axes were employed.

The most important results reported in Part I can be summarized as follows.

1. A loss of vision is not attended by retardation in verbal comprehension. In those who have become blind early in childhood, verbal comprehension continues to develop till the age of 25 or so.

2. When the tactual spatial tests were performed permitting the subject to make use of the vision he had, it turned out invariably that those with less impaired vision did better than those with more impaired vision. On the other hand, when the seeing performed the same tests blindfolded, there was no difference between them and the totally blind. This theoretically important result is discussed in the report. The spatial tests proved to depend on the age of onset and the duration of blindness in a surprisingly low degree. This was another theoretically important finding.

3. On tests of the immediate memory for words the blind did slightly better than the seeing. It is noteworthy that the difference was clearly more marked in the test involving meaningless pairs of words than in the test where the words constituting the pairs were interrelated in a meaningful way; in other words, wholly mechanic, immediate memory based on the sense of hearing is better developed in the blind than in the partially sighted and the seeing. There was some evidence to suggest the existence of a tendency for the early blind to do better in memory tasks than those who have become blind at a later age do; and it was found that memory performances tend to correlate positively with the duration of blindness.

4. No intergroup differences were found in arithmetical rea-

soning.

5. As regards numerical ability proper (mental arithmetic), the blind seemed superior to the other groups. A noteworthy finding was this: the congenitally blind and those who had become blind very early in childhood formed the group highest in mental arithmetic

6. As regards Seashore's musical aptitude variables, the seeing males were inferior to the blind males in Pitch Discrimination, Tone Memory and Rhythm, but they were superior to the blind males in Loudness Discrimination. The results in Seashore's variables were not found to depend on the age of onset or duration in any appreciable degree.

7. No significant intergroup differences were found in tactual discrimination. However, there may be a tendency for the totally blind to be slightly inferior to others. No dependence upon the age of onset or duration was observable for certain.

8. The totally blind were also somewhat inferior to the other subjects in kinesthetic mastery of hand positions. Neither the age of onset nor duration of blindness appeared to be of relevance.

9. In the dexterity tests it was discovered that vision, however deficient, was of decisive value. There was a mild tendency for those born blind to be inferior to the adventitiously blind. As for duration, both those who had been blind for a short time (1 to 3 years) and those who had been blind for a long time (13 to 20 years) were better than the others. Mastery of near space through visual images and the gradually increasing familiarity with tactual near space may be factors accounting for the result.

The factor analyses were made from the results of four groups of subjects: totally blind males, partially sighted males, all congenitally blind subjects, and seeing males. In addition, certain comparisons of factor structures were carried out.

The main results were as follows. Blindness is not in itself a factor hindering differentiation of the ability structure. One result of theoretical importance was the following: the factor analyses of the totally blind males and the congenitally blind subjects showed that the tests determining a spatial factor with the seeing also form, when they are performed tactually, a distinct factor on their own. This suggests the existence of a primary spatial factor, independent of the sense modality involved. Nevertheless, the factor analysis carried out with the seeing subjects revealed that the visually performed spatial tests and the tactually performed spatial tests spanned two mutually independent factors. Future research will probably reveal whether this circumstance is attributable to central or peripheral functions.

In the case of the blind, two analogous tests measuring the discriminative sensitivity of the touch and hearing senses, respectively, constituted a separate factor on the basis of their common variance. This factor correlated mainly with the factor formed by Seashore's musical aptitude variables. No factor corresponding to it occurred in the analyses of the partially sighted or the seeing. Mechanic memory correlated with the other ability test performances definitely more closely in the blind than in the seeing.

Only some of the most important results yielded by this extensive project were referred to above. The publication reporting the project includes, in addition, a theoretical discussion of certain topics in the psychology of perception and a survey of previous test-psychological studies of the blind.

The project is being continued to elucidate the following points, among others: What differences, if any, can be found between the blind and the seeing in the correlations of speed and power tests representing various factors? Can the spatial factor, for example, be divided into different kinds of subfactors depending on whether the subjects are blind or seeing?

An Analysis of the Components of Orientation Ability and Mental Manipulation of Spatial Relationships

In this study, orientation ability was analyzed and the relationships of the components of this ability to the rest of the ability structure were investigated. A distinction is made between the terms "mobility" and "orientation": in principle, "mobility" refers mainly to a technical readiness and an acquired reaction ability, while "orientation" is used to refer to the apprehension of spatial directions, relationships, and distances. The two concepts overlap in part; the obstacle sense, for example, involves both mobility and orientation. Mobility has been studied comparatively extensively (e.g., the use of varied technical traveling aids has been investigated), whereas orientation ability has not been studied much.

This study is concerned with the orientation ability of the blind and seeing, and with the analysis of ideational manipulation of spatial relationships in general. It consists of three parts: a study of the blind, a study of the seeing, and a comparative analysis of the two.

The central issues dealt with in the study of the blind were related to the following questions.

1. To what extent are the obstacle sense of the blind, the mastery of spatial locomotion patterns, the ability to maintain the direction of locomotion, and sound source localization mutually in-

dependent traits?

2. How are the hypothetical components interrelated?

3. How are these components related to the age of onset and duration of blindness and to chronological age?

4. How is tactual spatial ability (i.e., the ability for operations with spatial relationships on the basis of tactual impressions and images) associated with the recognition and mastery of kinesthetico-proprioceptive locomotion patterns?

5. How is the obstacle sense dependent on various audiometer variables, pitch discrimination and loudness discrimination?

6. How is the recognition and mastery of locomotion patterns traveled and the ability to maintain the direction of locomotion dependent on the above variables?

7. How is sound source localization related to the auditive variables and tactual discrimination sensitivity?

8. How is two-hand coordination, presupposing mastery of spatial directions, related to tactual spatial ability and kinesthetico-proprioceptive locomotion performances?

9. How are the discriminative sensitivities in the tactual and auditory spheres interrelated?

10. How does each of the above variables correlate with intelligence?

The group of the seeing was included to make possible a study concerning the interrelationships of spatial faculties associated with various sense modalities. More in particular, the intention was to approach from varied aspects question of how orientation ability is anchored in spatial ability. The problems dealt with included the following questions. How is visualization ability related to the corresponding tactual spatial ability? How is visualization ability associated with the recognition and mastery of and memory for kinesthetico-proprioceptive locomotion patterns? How is tactual spatial ability associated with the recognition and mastery of and memory for kinesthetico-proprioceptive locomotion patterns? How do the abilities to maintain the direction of locomotion and to estimate the distance traveled correlate with the above variables? How do the dexterity variables, included for the purposes of control and calling for mastery of near space, correlate with all the above variables? How is each of the above variables dependent on the person's chronological age and his general intelligence?

The comparative analysis of the blind and the seeing involved the following problems, among others. Are there differences between the two groups in how the spatial tests based on tactual and kinesthetico-proprioceptive sensations correlate with one another? How do the performances of the two groups on these tests differ from each other quantitatively? Are there differences between the two groups in the dependence of spatial test performances upon the subjects' chronological age and general intelligence? How do the blind and the seeing differ, as groups, in the variables indicating the ability to maintain the direction of locomotion and the ability to estimate distances? How do the blind and the seeing differ, quantitatively, in performances requiring two-hand coordination?

The group of subjects consisted of 53 totally blind males, aged 17 to 50. The control group comprised 43 males. All the subjects participated voluntarily in the study.

The mean age of the blind was somewhat higher than the mean age of the seeing; judging by the general norms for intelligence, both groups were somewhat above the average.

The study was almost entirely factor analytical. Factoring took place through the principal axis method, and the Varimax method was used in rotation into orthogonal axes. In addition, the *t* test was used to test the differences among the group means for significance.

The most central results yielded by the study of the blind were the following.

1. The hypothesized components of orientation ability actually proved to be comparatively independent of one another.

2. The following interrelationships among the components were ascertained. The obstacle sense, sound localization and the maintenance of the dirrection of locomotion had a relatively large common variance: these three components obtained markedly high loadings on one and the same factor. What is concerned is, obviously, integration of auditory impressions, and in this way the obstacle sense is dependent, in one way or another, on the localization of the source of echoes. In addition, the ability to maintain the direction of locomotion and the mastery of spatial locomotion and the mastery of spatial locomotion patterns had considerable common variance.

3. The obstacle sense had a significant connection with pitch discrimination and the audiometer variables, notably those involving ultrasonic frequencies.

4. The most unexpected result was the finding that the tests measuring the mastery of spatial locomotion patterns correlated

significantly with the audiometer variables throughout the entire range of frequencies.

5. On the other hand, these locomotion pattern tests fell within the same factor as the tactual spatial tests.

6. In the locomotion pattern tests, three components were distinguishable: spatial ability, general sensory sensitivity, and integration of auditory sensations.

7. There was a strong positive correlation between the obstacle sense and an early onset of blindness and with the duration of blindness.

8. The spatial locomotion pattern performances also correlated with the age of onset: there was a positive relation between good performances and an early onset. This finding was against expectations, and it shows that the significance of transposition into visual images has probably been overestimated in the literature.

9. The early-blind were also superior to the others in the ability to maintain the direction of locomotion.

10. The obstacle sense and locomotion pattern performances were wholly independent of verbal intelligence.

The most central findings of the study of the seeing were the following. The visually and tactually performed spatial tests correlated strongly with each other. Their high correlations with certain other tests revealed that their variance was mainly explicable in terms of general intelligence and the readiness of operating in near space. The locomotion pattern performances hardly correlated at all with either the visual or the tactual spatial tests. This result was in part contrary to expectations, and thus a closer theoretical analysis is called for. The ability to maintain the direction of locomotion was, in the case of the seeing, almost entirely independent of the other locomotion pattern tests.

The results yielded by the comparative analysis of the blind and the seeing were the following. The hypothesis according to which the integrating effect of vision tends to increase the intercorrelations of the tests based on tactual and visual sensations was not supported by the results. In the case of the seeing, the performances tied up with these two sense modalities did not correlate at all; in the case of the blind, by contrast, highly significant correlations emerged. In addition, compared with the seeing, the blind did better on each of the tactual and kinesthetico-proprioceptive spatial tests. In the case of the seeing, the locomotion pattern tests had no connections with any components of mental ability; in the case of the blind, on the other hand, they correlated with the tactual spatial tests at least. The blind were also superior to the seeing in the ability to maintain the direction of locomotion; the difference was definitely smaller, however, than in the locomotion pattern performances. Moreover, the blind were superior to the (blindfolded) seeing in two-hand coordination.

Only some of the most central results with a wide theoretical bearing were listed above. In the research report itself, these are discussed in greater detail.

The project is being continued with the object of investigating the following points, among others. To what extent are the blind and the seeing able to transpose spatial gestalts based on tactual impressions into kinesthetico-proprioceptive locomotion patterns, and vice versa? How are these properties interrelated? And how do they correlate with pure tactual gestalting; pure kinesthetico-proprioceptive locomotion pattern formation; and the other components of orientation ability?

How is the production and mastery of successive auditory gestalts associated with other spatial processes? This question can be studied through Dr. Leslie Kay's ultrasonic aid, for example. The subject is required to observe, with the aid of this device, a metal plate cut into a specified shape; following this, he has to choose, visually or tactually, a figure similar to it from among a number of alternatives. A series of experiments of this kind is under way, the intention being to approach the problem of intermodal spatiality from still another aspect.

How far do the intercorrelations of spatial tasks associated with different sense departments vary as a function of time and training? It seems plausible that if a group of seeing subjects can be administered tactual and kinesthetico-proprioceptive spatial tasks of the same type repeatedly during a long period of time and if the obvious mistakes committed by them are invariably corrected, the interindividual differences due to the intervening variables gradually disappear; then the variance would be due to the central spatial functions.

What differences between the seeing and the blind are ascertainable in the intercorrelations of various stimulus and difference threshold variables? The sense modalities of prime interest are, of course, kinesthesis, touch and hearing. Judging from the results of the study reported here, differences in many orientation performances appear to be based on such differences in correlations. A systematic differential psychological special study would be neccessary here to furnish a theoretical basis.

On the Ability for Orientation in the Absence of Vision

The paper gives a survey of the theories of the obstacle sense and reviews the empirical results obtained. In addition, certain hypotheses are advanced concerning the interrelations of various phenomena and factors. In the main, however, the paper is a review of the experimental work done and the theories presented elsewhere, and, notably, in the United States; hence it was not regarded as necessary to translate the paper in English.

Experiments on the Obstacle Sense and the Use of an Ultrasonic Aid
by Jyrki Juurmaa and Soili Jarvilehto

The paper reports experiments on the perception of the distance, size, and material of objects relying on natural echo impressions and by means of Dr. Leslie Kay's ultrasonic aid. This investigation was in the nature of a pilot study.

PART II: STUDIES ON THE DEAF

On the Ability Structure of the Deaf

This was an analysis of the ability structure of the deaf and a comparative analysis of the ability structures of the deaf and the hearing, primarily with respect to the following hypothetical factors: verbal ability, reasoning, visual (spatial) ability, visual memory, and perceptual speed and accuracy.

The subjects were pupils of schools for the deaf, aged 12 to 17 (49 boys and 45 girls). The corresponding control group, made up of hearing elementary school pupils, was accurately matched as regards age. As for the sampling, the groups were representative of their respective populations, except for the circumstance that the group of hearing was likely to be below the average intelligence because the brightest children over 11 usually attend grammar schools. Thus, insofar as the hearing are superior to the deaf, sampling error can be said to be in the safe direction.

The study was differential psychological in nature. Apart from the comparisons of the means for the deaf and the hearing, correlative relations provided the basis for the analysis. Factor analyses were made separately for the following groups: the total group of deaf, the deaf girls, the deaf boys, the total group of hearing elementary-school pupils, the hearing boys, the hearing girls, and, finally, the control group of hearing adults. The factor analyses were carried out employing at least one of the following two procedures: objective mathematical orthogonal rotation through the Varimax method, starting from the principal axis matrix; Ahmavaara-Markkanen's Cosine Rotation, starting either from the principal axis matrix or from the centroid matrix. Rotation was carried out through the Varimax method for all the groups. To compare the factor structures of the total group of the deaf and the total group of the hearing, transformation analyses were performed in both directions. (In other words, the factors obtained with the deaf were transformed into the factor space of the hearing, and, correspondingly, the factors of the hearing were transformed into the factor space of the deaf.)

Results

Comparison of the Means

The deaf were superior to the hearing on none of the variables. With regard to visual ability of a concrete kind, visual memory and perceptual speed and accuracy, the groups were most nearly similar. Nevertheless, on the test of perceptual ability where letters served exclusively as optic, perceptual material devoid of any symbolic function, the hearing were definitely superior to the deaf, just as they were above the deaf on the test of nonconcrete visualization. On verbal ability, numerical ability and reasoning the hearing were definitely superior to the deaf. Since the sampling error was here in the safe direction, the results can be regarded as so much the more convincing.

Comparison of the Factor Structures

Considered as a whole, the factor structure of the deaf proved less differentiated than that of the hearing. The principal results were as follows.

1. For each group of the deaf there emerged a general verbal ability factor, on which the more reliable of the reasoning tests, based on pictorial symbols, and the more difficult of the numerical tests had high loadings. What was involved was, perhaps, a general, undifferentiated ability to operate with symbols. No corresponding factor was obtained for the hearing.

2. The standard deviations of the verbal tests were small for the hearing, and the tests were possibly split up between different factors on the basis of nonverbal variance. Two tests with the lowest standard deviations constituted a factor on their own. This was termed a verbal carefulness factor. Correspondingly, two tests with a higher discriminative power formed a factor regarded as the verbal intelligence factor proper for the hearing.

3. The most amazing result with the hearing was a factor consistituted by three tests, one of which simply involved the naming of optic figures, while the other two were concerned with reasoning based upon pictorial symbols. This was referred to as a factor of recognition of correspondence between pictorial and verbal symbols.

4. No pure factor of numerical ability was obtained for any of the groups of deaf subjects. By contrast, such a factor was found for every group of hearing subjects. In the case of the deaf,

numerical ability was associated partly with verbal ability and partly with visual ability.

5. The visual tests based upon immediate perception formed a factor on their own with the deaf: the test which required operating with spatial images, independent of perception, was separate from the factor.

It was assumed that the variance of the last-mentioned test was partly associated with verbal ability and perceptual speed. A distinct uniform factor formed by all the tests of visual ability emerged for the hearing. The tables concerned with transformation analysis contain specific information about the invariance of the variables and factors in shifting from one group to another. The factor structure of the test battery - or, in a sense, its power of differentiation - was also checked employing the group of 16- to 22-year-old subjects with normal audition.

In the discussion chapter the possible interpretations of the results are considered by factors. Particular attention is devoted to the nature of the abstract thinking of the deaf and, especially, to the significance of verbal retardation for it. Particular consideration is also given to numerical retardation in the deaf.

An Analysis of the Lipreading Ability of the Deaf

The study is concerned with lipreading ability. The aim is to investigate the intercorrelations of various components of lipreading and the correlations of these components with certain other variables. The most important problems are: What are intercorrelations amongst lipreading from a film prepared for the purpose of the study; lipreading from the lip area of a person speaking in natural test situation; and the judgements of the lipreading performances by a person sufficiently familiar with the subjects? In other words: Can these variables be considered to measure the same function? How far are lipreading variables relating to single sounds, separate words, and meaningful sentences intercorrelated? What is the relationship between lipreading ability and various other traits of ability structure?

The subjects were pupils of the schools for the deaf. Altogether there were 115 subjects (52 girls and 63 boys). The age distribution of the subjects was between 13 to 19 years.

In the statistical treatment of the material Bravais-Pearson correlation coefficient was used; in the factorial analysis the factoring was carried out through Hotelling's principle axis method, and the rotations through the orthogonal Varimax method.

The most important results and conclusions are the following.

1. The lipreading made from the mouth area of a person present in the test situation, the lipreading made from films, and the evaluations that the teachers have made of the lipreading of the pupils correlate to such a degree that these different variables can be considered to measure about the same thing.

2. A relatively strong connection exists between the lipreading of separate sounds, separate words, and whole sentences. However, the lipreading of the girls has a tendency to differentiate into two factors: one representing meaningful lipreading of rather large wholes, where the gaps are completed with the help of reasoning, and the other being a representative of "mechanical" and optically exact lipreading of concise units.

3. The correlations and factor analyses suggest that lipreading is a comparatively independent ability, which has, however, correlative associations with verbal ability: the correlations grow strong as the units to be lipread grow larger. Lipreading is not connected with the purely optical recall of the movements of the mouth area nor with the so-called social intelligence or sociability of the subjects.

4. Within the limits of the investigated age group the lipreading is not dependent on age of the subject, but the residual hearing is of some help in learning to lipread and in the lipreading process itself.

5. The situation in which the lipreading is performed influences the success of the lipreading to a considerable extent. It is easier to read from the lips of an actual person speaking in a natural situation than it is to lipread from the mouth area of a person on film. The distinctness and carefulness of articulation also have a great influence on the accuracy of lipreading.

Effects of the Loss or Essential Impairment of Auditory Functions on Personality Characteristics

The paper is concerned with the study of the character traits of the deaf. Initially an attempt is made to analyze the "manifest" or "evident" factors that may cause intergroup differences in certain character traits. A brief summary of the already identified factors in the three groups of factors is following: stock of concepts, adherence to the principle once adopted, retardation of abstract reasoning, uncertainty and low constancy of expectations, narrow frame of reference, difficulties in expressing emotions and thoughts, personal nature of information and its paucity, lack of auditory impulses stimulating the organism, narrow range of contacts, and lack of auditory associations. *On the basis of information on these manifest factors, seven general hypotheses were derived concerning characterological traits.*

In the empirical part an additional hypothesis, independent of those referred to above is advanced: the differences among these hypothetical general characteristics will be reflected as differences in certain test performances, here, in Wartegg test performances. As regards the results, the following central points should be mentioned. None of the results were actually inconsistent with the hypotheses and every hypothesis was supported to some degree by the results. Three facts, independent of one another in principle, were revealed for certain: the deaf subjects' drawings were less adequate, poorer in expression, and lacking more in content than those of the hearing. The sample of hearing subjects consisted of 140 school children over 12, and the control group was made up of 120 matched hearing subjects. A discussion on how the theory could be further elaborated concludes the paper.

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ELECTRONIC AIDS FOR BLIND PEOPLE*

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INTRODUCTION

The investigation described below was carried out as part of a program of research by St. Dunstan's into the possibility of electronic aids for blind people. The devices concerned were of two types, guiding aids and reading aids: the former intended to make up to some extent for the loss of distant vision and the latter make available to blind people the large amount of literature not available in braille.

GUIDING AIDS

Basic Principles

When, at the end of the war, the principles of radar became known many people felt that there might be some possibility of applying the same principles in a portable device. If this enabled blind people both to detect and avoid obstacles they might be able to find their way about without escort to a greater extent than before.

Experimental work in this country and in the United States aimed to investigate thoroughly all the various possibilities, to discover whether any of the wartime advances in technique could be applied and, if not, what further advances would be necessary before a practical guiding device could be made.

In attempting to design suitable devices to be tested out with the assistance of blind people the basic principle of radar equipment was adopted, that is, when the exploring beam is intercepted by an object the later reflects some of the energy in the beam back to the instrument where it is detected and thus informs the user of the presence of an obstacle. The character of a radar beam, and in particular the wavelength, makes it unsuitable for locating small objects at ranges of a few feet. Because of this it is necessary to look around for some other form of exploring beam. The most promising alternatives being beams of light and beams of sound and ultrasonic energy, various devices using each were constructed. Details of the design of these have been given elsewhere (1).

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Preliminary Tests on 'Obstacle Sense'

Before the various devices were ready, preliminary tests were made in an attempt to ascertain whether the blind man's ability to 'sense' the presence of obstacles was entirely accounted for by his interpretation of echoes from them. Many blind people who have the ability to sense obstacles do not attribute it to hearing. Because awareness of an obstacle is frequently accompanied by a 'tingling' sensation on the face they are apt to explain it in terms of some sense vaguely described as 'facial vision.'

These tests were made in a soundproof room 8 by 10 by 8 ft, and the blind man cooperating in the test was seated near the center of the room, while objects of various shapes were supported in positions unknown to him. He was then asked first to point out their position and secondly to touch them. It was found that great care had to be taken in the still room to avoid making even the slightest sound when placing the objects in the test position. Even the rustling of a sleeve was enough to give away the position and it was found useful to provide some distracting sound, such as someone talking, while the object was being placed in position. If the blind man remained absolutely still and there was no other sound present in the room, he was unable to detect the object at any distance unless its temperature was sufficiently different from the ambient temperature. For example, a hand may, with difficulty, be detected a foot away by the heat radiated from it.

When the blind man was allowed to make sounds of his own choosing he was able to detect readily any objects of more than about 1 sq ft projected area within 4 to 5 ft unless these objects were facing in such a direction that no sound could be reflected directly back towards his ears. Preference was shown for a sharp sound such as the click produced by snapping two fingers together, except when an object within 2 ft was being located, when a rustling sound or a hiss appeared to give more assistance. Location of an object was rendered considerably easier if the blind man was allowed to alter the position of the sound source. This presumably altered the strength of the sounds reaching his ears directly, relative to that reaching his ears via the object, and provided additional information on which to base his judgment. Detection of any object, however large, became very difficult and extremely unreliable immediately the range of the object became comparable with the distance to the nearest walls of the room. It is probable that this difficulty was caused by masking of reflection from the object by the many reflections from the walls of the room.

The accuracy with which the object could be located was difficult to estimate. The blind man was first asked to point in the direction of the object and state its distance in terms of some unit, such as feet or arm's lengths, with which he was familiar. Unfortunately, blind people as a whole have a very poor sense of the position of their hands and arms. This is of course understandable, since they are never able to correct positional errors by sight. In consequence a blind man concerned in these experiments might, while having a clear idea as to where the object was, indicate its direction inaccurately, being frequently 10 or 20 degrees out, usually with a considerable bias in one direction. It was in order to eliminate this difficulty that the blind man was also asked to touch the center of the object, and he was normally able to do this with an error of seldom greater than 5 degrees. In the same way errors in estimating the range arose largely from a misconception as to how far '1 ft' really was. Though able to demonstrate by touch that he knew the distance of an object a blind man would frequently give a much less accurate verbal estimate.

Various artificial sources of sound were tried as an aid to location, including tones, thermal noise and single and repeated pulses of sound with a variable frequency content. In general, high-pitched pulses of sound or 'clicks' showed a marked superiority, though at short ranges thermal noise appeared as effective for detecting and locating objects provided the high frequency content was not removed. The important qualities in the pulses appeared to be the shortness of the pulse and the presence of high audio frequencies. If these two factors were present the other characteristics mattered little. If the blind man was allowed plenty of time to locate an object he preferred to do it by producing single pulses under his own control and in this way was able to obtain an accurate idea of the object's position. If the object was only present for a short while it was found better to provide a succession of pulses at a fast rate, this making it possible to estimate the object's position most accurately in a short period. It was, however, necessary to limit the repetition rate when searching for distant objects to prevent the echo being masked by the following pulse. For distant objects it was also found advantageous to shield the source, thus reducing the sound reaching the ears directly.

Comparison of Devices

On the basis of these preliminary tests it was decided to construct one acoustic device working at audible frequencies. In this the internal detector for echoes could be omitted as the user could listen directly to the sound reflected from any obstacle. When a practical comparison of the various devices was made it was found that this device in particular stood out as being more popular. The principal reason for this appeared to be that a wide beam of sound could be employed, since directional location of the audible echo could be accomplished binaurally and did not depend on the narrowness of the beam as in the other devices. The wide beam of sound eliminated the lengthy scanning procedure, which is unavoidable if the user of a narrow beam device wishes to make certain that no obstacle is missed but which renders progress unduly slow. This device, the 'clicker' also had the advantage in weight (1-3/4 lb) and battery life (750 hr) over the devices incorporating an internal detector for the reflected energy. Another advantage of omitting the internal detector and amplifier system is that all the information which may be obtained from the nature of the reflections from an object is preserved intact. Much of this is lost if the echo is heard through an amplifier because of the unavoidable distortion when the power consumption must be reduced to a minimum and the sensitivity kept high.

Field Tests

For the reasons just given, and to reduce the considerable time which thorough training in the use of each device involves, it was decided to test only the 'clicker' device extensively. Several groups of blind people, including children at three schools in the London area, were given instruction in its use. At these schools the instruction culminated in a test in which the children had to find their way along an unknown route, some with the assistance of the clicker and some without it. Those who made the outward journey with the clicker returned along the same route without, and vice versa. They were timed on both journeys and note was made of the number of times it was necessary to correct one of them who had departed from the correct course. It is proposed to quote the results of these tests in detail as they are typical of the conclusions arrived at with the other groups of blind people.

At the first school the test route ran through streets in the neighborhood of the school which were previously unfamiliar to any of the children. It was chosen because it provided a variety of different situations such as a blind person might expect to encounter. For 30 yd it was necessary to find a way along a gravel path between scattered bushes, then a left turn led on to a pavement beside a road carrying fairly continuous traffic. This road was provided with additional obstacles in the form of a bus stop and a belisha beacon. After 84 yd the route turned left again on to a pavement beside a quite street in which there was a large number of obstacles. The first of these was a telephone box projecting from the fence and the second a wide break in the fence where a drive entered private grounds. Beyond this a row of eight trees and one lamp post, irregularly spaced, flanked the fence. The distance from the corner to the end of the street was 120 yd.

Before departing, the children were given a brief description of the route but were not informed of the position of any of the obstacles which have been mentioned. It was noticeable that, especially on the outward journey, those with the clicker were more at ease than those without who seemed, in some cases, afraid of the possibility of colliding with some obstacle. Of the five children who returned without the clicker three made considerable use of the knowledge, gained on the outward journey, that there was a fence running beside them nearly the whole length of the route. They touched this every two or three paces and were thus able, in some cases, almost to run back. The other two made use of footfall echoes from the same fence, one of these returning entirely without touching the fence. Those returning with the clicker obviously felt that they were expected to return with its aid alone and refrained from touching the fence.

The mean times taken by the children covering the course are given in Table 1.

Table 1. *Mean times taken by children to cover the course* (*ten children aged* 11–15)

Journey	Mean time (min.)	Standard deviation (min.)
Outward with device	4·96	1·7
Outward without device	7·08	2·7
Inward with device	4·24	0·94
Inward without device	2·56	0·47

In the second school, one test route ran down a street with houses on both sides for about 20 yd and then continued down a narrow lane for 170 yd with a grassy bank surmounted by a hedge on either side. In this section there were several open gateways where drives passed through the bank into private grounds. After descending a small hill for 158 yd the route turned to the right out of the lane into a newly made unfenced road running across a field in which new houses were being built. As there was no well-defined edge to the road here, the route had to be followed by noticing the different surfaces underfoot at the side of the road. A further obstacle in the form of a parked shooting brake stood in a direct line from the corner to the end of the route 40 yd farther on.

Errors were made by several children, the commonest being to turn to the right up one of the several drives instead of waiting till they reached the road junction. None of them made this mistake on the return journey. On reaching the junction none failed to turn right but many, instead of turning at right angles to their previous direction, went obliquely across the road. This may have been partly due to the misleading effect of the slope of the ground and partly to the absence of any guiding fence by the side of the road. Most of the children liked using the clicker and two inquired when it would be possible for them to have one of their own.

The mean times taken by the children covering the course are given in Table 2. Examination of the times in Tables 1 and 2 suggests that while on the unknown test route the clicker affords some assistance, the reverse is the case on a known route, even if, as in this case, the route is only being traversed for the second time, and that in the opposite direction. It is also clear that the experience gained on the outward journey results in a much greater speed on the return journey whether the clicker is

Table 2. *Mean times taken by children to cover the course* (*ten children aged* 14–18)

Journey	Mean time (min.)	Standard deviation (min.)
Outward with device	7·94	3·3
Outward without device	9·54	3·8
Inward with device	4·94	0·88
Inward without device	4·76	1·2

used or not. The probability of statistical significance in the difference between the times with and without the clicker on the outward journey is not great. The superiority of the clicker is significant on a 3 percent level by the *t* test only in the case of the first school. Taking both schools together the difference is significant on a 1 percent level. The difference between times on the return journey with and without the clicker is also significant on the 1 percent level. The most reliable evidence is in respect of the benefit of experience and is significant on the 0 to 1 percent level. It is also of interest to note that the standard deviation of times is very much lower on the return journey, showing that the speeds are less erratic.

A younger group of pupils aged 10 to 11, at the second school, went through a similar test over a shorter and rather simpler course running down a lane between steep banks, over crossroads and beneath a railway bridge. Only one error had to be corrected, that of a child who on the return journey lost all sense of direction at the crossroads and, turning completely round, would have gone back towards the bridge.

The third school catered for children from 5 to 10 years of age so a very short straightforward course was chosen for a test. If anything, it appeared that on this very simple course the clicker was a drawback rather than an aid since the children with it took great care to scan their path carefully. Those without, on the other hand, walked without hesitation along the footpath which formed the test route. Some of these used the oak-paling fence to one side either as an audible or tactile guide, others used the grass on either side of the path as an indication that they were straying.

As only a few children were concerned in each of the latter tests, and no significant differences existed between the two schools as regards the influence of experience and the use of the device, the results have been combined in Table 3.

Table 3. *Mean times taken by children to cover the course* (*eleven children aged* 11 *and under*)

Journey	Mean time (min.)	Standard deviation (min.)
Outward with device	4·29	1·1
Outward without device	4·03	0·82
Inward with device	3·37	0·90
Inward without device	3·24	1·0

fence running beside them nearly the whole length of the route. They touched this every two or three paces and were thus able, in some cases, almost to run back. The other two made use of footfall echoes from the same fence, one of these returning entirely without touching the fence. Those returning with the clicker obviously felt that they were expected to return with its aid alone and refrained from touching the fence.

The mean times taken by the children covering the course are given in Table 1.

Table 1. *Mean times taken by children to cover the course* (*ten children aged* 11–15)

Journey	Mean time (min.)	Standard deviation (min.)
Outward with device	4·96	1·7
Outward without device	7·08	2·7
Inward with device	4·24	0·94
Inward without device	2·56	0·47

In the second school, one test route ran down a street with houses on both sides for about 20 yd and then continued down a narrow lane for 170 yd with a grassy bank surmounted by a hedge on either side. In this section there were several open gateways where drives passed through the bank into private grounds. After descending a small hill for 158 yd the route turned to the right out of the lane into a newly made unfenced road running across a field in which new houses were being built. As there was no well-defined edge to the road here, the route had to be followed by noticing the different surfaces underfoot at the side of the road. A further obstacle in the form of a parked shooting brake stood in a direct line from the corner to the end of the route 40 yd farther on.

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Though the mean times with the clicker are slightly greater in Table 3 the result has no statistical significance. The reduction in the times required on the inward journeys is significant only on a 5 percent level.

The Results

The most important fact among the results just quoted is the greater ease and speed with which the course is covered the second time when it has become slightly familiar. It would appear that a device such as that used in these tests ceases to have any great use once a route and the positions of any obstacles along it are known. It would therefore be unlikely to become popular with capable blind people covering a well-known route regularly. What is not brought out by the figures quoted but seems of considerable importance is that while the blind children were being trained to use the device their capability at finding their way around without any device also increased considerably. Many blind adults too, in learning to use echoes produced by the artificial sound source, began to appreciate the rather more subtle echo pattern produced by their own footsteps. It is interesting to note that the mean speed at which the test courses were covered was 2-1/4 mph, a reasonable walking speed even for a sighted person.

Conclusions

In view of the foregoing we think that the desirability of deliberately training blind people in the art of 'getting about' cannot be too highly stressed. It is also thought that, while no guidance device can be recommended for regular use, a simple directional audio frequency source such as that used in these tests might be invaluable as a training device for children and especially for recently blinded adults.

READING AIDS

Conversion of Print to a Sound Code

The ideal reading machine would perhaps be one which would automatically scan the lines on a page of print, 'recognizing' the words over which it passed, and would pronouce these for the benefit of the blind user. While there is nothing fundamentally impossible in such a machine the expense would be prohibitive. Even attempts at automatic recognition of individual letters necessitate such elaborate instruments that their cost would be far beyond the reach of most people.

A more practical alternative instrumentally, is a relatively simple form of machine which converts the printed characters into a sound code which may then be interpreted by an experienced reader in terms of the letters which are being scanned.

Such an instrument, the Optophone, was made by Messrs Barr and Stroud in 1918, and though there have been recent attempts to make similar instruments none of these have come into use. The original Optophone was handicapped by the use of photocells less sensitive and stable than those now available and the sounds it produced were in consequence rather weak and variable. Alterations were made to a number of Optophones to improve them in this and other respects, and four blind people cooperated in a test to determine whether this type of instrument showed any promise as a practical aid which would be of real use to blind people.

One of the alterations was in respect of the sound code employed. The Optophone scans printed matter by means of six spots of light which cover a vertical cross-section of the line of print. This set of spots moves horizontally along the line so as to scan in turn all parts of each successive letter. As each spot of light falls on a black area of a print character a corresponding tone is heard by the reader, who is thus enabled to decipher the shapes of the letters and read the text. After experimenting with various combinations of tones with the cooperation of the blind readers it was decided that the chord *G C D E B C* made reading most easy and rapid.

The Blind Readers

Of the four readers, two had learned to read on the original Optophone a few years after it was first produced and had used it on and off up to about 1940, when there was difficulty in obtaining replacements for the selenium photocells. Both were keen to start using the Optophone again when the fitting of vacuum photocells made this possible. The other two readers used the Optophone for the first time after the modifications had been carried out, one starting in the summer of 1948 and the other in the spring of 1949.

The progress of the four readers is shown in Table 4, the date quoted being the number of months from the date at which a modernized instrument was first received. The reading speed, which was measured line by line, is expressed in seconds per letter rather than seconds per word because it was found that the use of the former unit consistently gave the lowest variance between results for different lines. This is presumably because the number of letters in a line is a better measure of the difficulty of reading it than the number of words.

Consistency of Reading Speed

The column 'mean letters per word' is included as it gives some indication of the complexity of the words of which the text is composed. A correlation between the reading speed and the difficulty of the text might be expected. In fact, there is a slight positive correlation in each case between the reading speed and the length

Table 4. *Reading speeds*

Test no.	Reader	Experience dating from	Date, no. of months from receipt of modernized instrument	Mean, seconds per letter	Standard deviation mean	Letters per word
1	E.	1948	3	5·8	0·38	3·8
2			6	7·5	0·56	4·3
3			10	2·3	0·52	4·6
4			12	2·1	0·44	4·3
5	F.	1926	4	1·2	0·54	4·1
6			4	1·6	0·94	4·4
7			4	1·1	0·23	3·9
8			7	1·0	0·29	3·9
9			7	1·4	0·41	4·2
10			10	1·9	0·65	4·2
11			13	0·81	0·50	4·2
12	H.	1949	2	4·3	0·66	4·0
13			4	2·3	0·51	4·1
14			7	1·2	0·48	4·3
15			10	0·98	0·21	4·0
16			10	1·0	0·31	3·8
17			13	0·98	0·29	4·3
18			13	0·95	0·21	4·2
19	J.	1918	6	0·45	0·35	4·1
20			6	0·34	0·23	4·1
21			10	0·34	0·36	4·1
22			10	0·30	0·07	4·0
23			11	0·34	0·33	4·9
24			11	0·33	0·22	3·9
25			22	0·33	0·28	4·1
26			22	0·30	0·55	4·3
27			22	0·37	0·81	4·2

of word and between the standard deviation of the reading speed, expressed in terms of the reading speed, and the length of word. There is a much greater correlation (significant on the 1 percent level combining results for all readers) between the reading speed and the standard deviation suggesting that the mean length of word is only a minor factor contributing to the difficulty of reading a text.

Considering the readers individually it will be seen that while the two who had used an Optophone previously maintain a relatively constant reading speed the two new readers increased their speed markedly during the first 12 months of use of the instrument. The most experienced reader (J in Table 4) maintains a consistent reading speed of about 40 words per minute and uses the instrument practically for checking (typewritten) correspondence and, to some extent, for reading matter unobtainable in braille. The average reading speed of all four after the new readers had become familiar with the instrument was 20 words per minute. It is interesting to compare this with the average speed of 130 words per minute at which these four readers can read braille and with an average speed at which a book is read aloud, about 150 words per minute. The four readers were all of high intelligence, having a mean IQ of 139 on a Terman and Merrill test adapted for use by blind people.

Conclusions

These results show that unquestionably it is possible for an intelligent person, who is willing to persevere, to learn to read with such an instrument. The speed attained is, however, limited and an appreciable effort is required during the learning period. For these reasons it seems unlikely that the instrument would appeal to any but a very small minority of blind people who, for one reason or another, require to read matter not available in braille and who are unable to obtain the assistance of a sighted reader.

SUMMARY

Experimental electronic aids for blind people have been constructed. These include Guiding Devices operating on the same principle as radar and Reading Devices intended to enable blind people to read ordinary printed matter. Instruments of each type have been tested with the cooperation of blind people. The results show that though both types of aid can be of assistance under certain circumstances neither would be likely to achieve wide popularity.

REFERENCE

REFERENCE

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USE OF TELEPHONE INTERVIEWS IN A LONGITUDINAL FERTILITY STUDY*

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INTRODUCTION

The value of longitudinal studies in the social sciences is widely recognized, and yet such studies are attempted only infrequently because of the considerable time and expense usually involved. The effort of locating and interviewing the same group of people at repeated intervals is often thought too great to be warranted, particularly as interest in the follow-up may center primarily on a small number of variables. Hence our experience in reinterviewing approximately 1300 women who participated in a study of the growth of Detroit-area families may be of value to others.

This study of social and economic correlates of fertility is based on a special probability sample representing white women in the Detroit Metropolitan Area who have recently been married or had a first, second, or fourth child. Early in 1962 (January-February) these women were interviewed at length regarding many aspects of their family situations and their expectations about the growth of their families. (This was done as part of the Detroit Area Study, a continuing program at the University of Michigan associated with the sociology and other social science departments and the Survey Research Center.) With this broad framework established, the same sample is to be reinterviewed over a period of years. Briefly, the aim of the research is to determine whether these families realize their expectations and to ascertain the relationship between shifts in expectation and other changes in their family situations.

Because the reinterviews were to be brief, telephone surveys were decided upon for the follow-up calls. As the original sample was not limited to persons who had telephones, we expected some house calls would be necessary, but we hoped that most of the interviews could be completed by telephone. It was recognized that surveys about fertility involve questions that some might consider too personal to discuss on the telephone. Nevertheless, we were encouraged in this plan by the experience of two colleagues.

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Dr. David Goldberg had conducted follow-up telephone interviews about family expectations in the Detroit area in 1954 (2). And Dr. William Mooney, in a study designed for eleven successive telephone interviews over a period of eight months, had obtained the high response rate of 93.3 percent (1).

PROCEDURES FOLLOWED

As a longitudinal study was being planned, measures were taken at the outset to encourage continuation in the study and minimize attrition of cases. The subject - family plans - was of intrinsic concern to the women selected, and their interest in the study was encouraged. The interviewers were asked to rate the degree of rapport during the interview and the respondent's interest. This rating was to assist in determining the interviewer's approach in the follow-up situation.

At the close of the first interview, each respondent was told that the study was to be a continuing one and that she would be called again to discuss any changes in her family situation or plans. As an aid in contacting her later, each woman was asked to give the names and addresses and telephone numbers (if possible) of three persons who would know where to reach her if she moved. This information was obtained from almost the entire sample.

Late in 1962 (October-December) the second interviews were taken. Prior to the interviewer's telephone call, a letter was sent to each respondent reminding her of the study and telling her she would be called in the near future. A brief report, limited to highlights of some of the findings from the first interview that would not prejudice responses in subsequent interviews, was enclosed. The material selected for this feedback was of special interest to the sample group. To keep attrition of cases to a minimum, every effort was made to make this contact as personal as possible and to encourage the respondent's interest in remaining in the study.

The interviewers were instructed to reach the respondent by telephone if possible. If the respondent was no longer at the former location and could not be found through the Telephone Company information, the interviewers were to do any necessary tracing through leads or contacts as long as these were within the continental limits of the United States. If the respondent had no phone, house calls were to be made unless the respondent had moved outside the Detroit Metropolitan Area. The cases in which the respondent had moved away and could not be reached by telephone were to be handled by mail interview. The interviewers were instructed to be as persistent as possible both in tracing the respondents and in obtaining the interview. They were also instructed to set the stage for a further interview by obtaining information about plans to move in the future and by being careful not to alienate any respondents who might be resistant on specific questions.

RESULTS

The response rate of 97.6 percent indicates the success of this effort. Of the 1304 women initially interviewed, 1274 were reinterviewed. Sixteen could not be located, and 14 refused to continue in the study. Of those reinterviewed, 15 had been permanently separated or divorced since the first interview, and hence were no longer eligible to continue in the sample. If the sample is defined as excluding these wom[illegible] the response rate is 96.5.

This high rate is indicative of the success of the technique for reaching respondents in this particular study. The high rate may reflect the fact that a woman with a small baby is relatively easy to locate and not averse to talking on the telephone. The subject matter - family growth and fertility - may also be favorable to a high response rate. In three fairly long house-to-house interview studies on this subject, the reported response rates are 91.1 percent (3), 89.8 percent (4), and 92.0 percent (5). These are significantly higher than the average response rates in surveys with probability samples without replacement.

The interest and rapport established at the first interview undoubtedly also contributed to the success in reaching respondents in the follow-up. Following the first interview, the interviewers rated 55 percent of the respondents as having evidenced high interest in the interview, and 40 percent as average. Rapport was also high, with 60 percent of the interviews rated as having excellent rapport and 32 percent as average. This initial high interest in the study carried over into the second interview situation.

Noninterview Cases

The small number of nonresponse cases does not warrant presentation of tabulations on the characteristics of the noninterview families. But it is quite clear that those who could not be interviewed the second time tend to come from a somewhat lower socioeconomic level than those who remained in the study. On each of three measures used - family income, husband's occupational class, and wife's education - the noninterview cases are characterized by lower status. The deviation of the divorced or separated cases is in the same direction. Although the noninterview cases are divergent from the total group, the number of cases eliminated is too small to produce bias in the continued sample.

Tracing Required

The initial sample consisted of recently married couples (zero parity), and couples who had just had a first, second, or fourth child (designated as first, second, or fourth parity). We expected that it would be more difficult to trace the respondents who had recently been married, because they were more apt to move. We also expected that the response rate would increase with increasing parity, since more children would be likely to mean both less mobility and higher probability that the mother could be found at home. In fact, the response rate was virtually identical for all four parities. It is true that somewhat more tracing was required to locate the zero parity group. In the total sample, 10.5 percent had to be traced through the contacts supplied at the previous interview. The percentage traced ranged from 12.8 for the zero parity group to 9.0 for the fourth parity, confirming expectations that families with more children are more apt to "stay put."

The overwhelming majority of the interviews - 91.3 percent - were completed by telephone. Of this group, 2.3 percent had to be called by long distance outside the Detroit area. A small minority, 8.3 percent, involved a personal call by the interviewer to the respondent's home. Less than 1 percent were completed by mail. (Mail questionnaires were sent to three respondents who had moved out of the United States and to two who had moved to the East Coast but had no telephones.) There was no significant variation by parity in the proportion of interviews completed by telephone.

Many of the respondents had moved between the first and second interviews. Most had retained their old telephone numbers, however, and others were traced in various ways. The proportion who moved between the two interviews was 24 percent for the whole sample, but, as expected, this varied greatly by parity, ranging from 35 percent in the zero parity to 10 percent in the fourth parity. The great majority of those moving stayed within the Detroit Standard Statistical Metropolitan Area. This made the tracing process easier and less expensive. At every parity the moves within the metropolitan area greatly outnumbered those out of the metropolitan area. However, except for the just-married group, the proportion of moves to locations outside the metropolitan area increased with parity. Families with more children are less apt to move, but if they do move they are more likely to move outside the metropolitan area. The Table below indicates the nature of the moves, by parity.

We can expect that the tracing required to keep respondents in the sample will increase as time goes on. Twenty-eight percent of the total group had plans to move in the coming year, and among the recently married group this figure was as high as 34 percent. Even among the fourth parity families, those least apt to move, 20 percent said they definitely or probably would move. For many this represents a hope, often a wish for more space to accommodate their growing families, and may not be realized. If past experience is taken as a guide, however, there will continue to be many respondents who move and must be traced. Particularly for those who have

PERCENTAGE OF RESPONDENTS WHO MOVED BETWEEN THE FIRST AND SECOND INTERVIEWS, BY PARITY

		Parity			
	Total	*0*	*1*	*2*	*4*
Living at same address as at first interview	76	65	65	80	90
Moved within metropolitan area	20	29	31	16	8
Moved outside the metropolitan area	3	5	3	2	1
Moved, not known where	1	1	1	2	1
Total	100	100	100	100	100
Per cent of all moves that were outside the SMA	12.1	16.7	9.7	11.9	15.2

already moved out of the area, the information about contacts who can be used in locating respondents will be increasingly important.

Even though considerable tracing is required, use of the telephone interview keeps the cost of interviewing down. This is true even though there were many toll calls and a considerable number of long-distance calls outside the Detroit area. About 2.3 percent of the interviews were taken by long-distance phone, and many more such calls were made in tracing respondents. Nevertheless, the cost per interview was very low compared with interviews taken in person. Comparative costs are difficult to determine because of varying length of interviews, but our best estimate is that using a telephone interview whenever possible rather than house-to-house calls resulted in savings of approximately 60 percent.

Reaction to Telephone Interviews

The respondents' reaction to the reinterview was very favorable. Nearly all remembered the first interview, and many expressed pleasure at being contacted again. Quite a number who had moved and received our forwarded letter wrote to say they hoped they could continue to be part of the study. There appeared to be no objection to being interviewed by telephone. Their cooperation may well have been influenced by the brevity of the follow-up interview.

The interviewers' reaction is not unrelated to the high response rate. To a number it represented a challenge; there was a bit of the Mountie's "get your man" in the situation, and they enjoyed exploiting their tracing talents. Without their persistence and ingenuity, the follow-up would have been less successful.

As of December 1, 1963, the third interview is nearing completion. The response rate has continue to be high; 98 percent of those interviewed on the first follow-up have been reinterviewed again. Of the total sample originally interviewed, 93 percent are still participating in the study and are eligible to continue to do so. Thus, after the third interview, this continuing group constitutes 87 percent of the original panel drawn and found eligible to be included in the study.

The quality of the data cannot be evaluated until later in the analysis process, but it is clear that it is possible to obtain apparently reasonable responses from substantially all respondents on all the questions. The number of cases of refusal to answer particular questions was negligible, although many of the questions dealt with topics that might be considered sensitive, especially in a telephone interview: pregnancy, fetal mortality, expectations about future births, and changes in income, for example. Apparently it is possible to obtain sensitive information through telephone interviews. This provides an economical method for conducting a longitudinal study.

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SCREENING FOR VISUAL IMPAIRMENT*

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Can a telephone survey effectively screen for visual impairment? To what extent is a telephone sample representative of households where visual impairment is present? Or, stated otherwise, will a telephone sample produce prevalence rates of visual impairment comparable to rates obtained by more traditional sampling methods; for example, personally interviewing a sample of all households (telephone and nontelephone) as in the National Health Survey and most other health studies? Is there under-reporting of visual impairment in telephone screening as compared with face-to-face interviews? How much trust should be placed in what people say about their eye trouble? Can acceptable data on visual acuity be obtained by nonmedical investigators conducting standardized vision tests in the homes of respondents?

These are the questions we sought to answer in a household survey of visual impairment. This study was designed and conducted by the American Foundation for the Blind in collaboration with Western Reserve University, in Cleveland during the winter and spring of 1963.

THE PROBLEM

Visual impairment is open to varying definitions, and any study of persons with eye disorders must begin with some statement about the criteria used to identify them. In simple medical terms, blindness means anything less than 10 percent of "normal" vision, and according to recent estimates its prevalence is slightly more than 2 per 1000 population, yielding a total of approximately 400,000 blind people (1). However, blindness as defined for purposes of welfare is arbitrary in the sense that it includes some persons who appear to function nearly as well as normally sighted people and excludes others who are limited in mobility and activity because of trouble in seeing.

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In our study we adopted the functional criteria used by the National Health Survey (2) for studying visual impairment. That is, we interpreted "visual impairment" to include all persons who reported serious trouble in seeing, even wearing glasses, and "severe visual impairment" to include all persons who replied negatively to the question: "Can you see well enough to read ordinary newspaper print with glasses?" The National Health Survey has estimated that there are approximately 3-1/2 million visually impaired persons (a rate of 19.8 per 1000), of whom nearly 1 million have severely impaired vision (5.6 per 1000 population).

In devising a strategy for locating cases of visual impairment, a basic assumption was that a fairly large probability sample of households would be essential to determine the magnitude of the condition and to provide a representative number of cases for analysis. Without such a sample, we would have missed both the "hidden" or unknown blind and the far greater number of persons who have severely impaired eyesight but are not regarded as blind.

In most states and large cities, those who become known to and listed by social agencies are chiefly the blind persons receiving public assistance or the people getting special services. As a result, serious bias exists in such lists, and we may assume that an important minority of the total blind population are unaccounted for because the agencies have been unable to reach them, such persons do not want to be reached, or they do not know they are blind. One of our aims was to test a method for getting information about this hidden group. As for visually impaired persons who are not regarded as blind, since no list or registration of such cases exists, there is no way to reach them other than through a household sample.

In view of the relatively low prevalence of visual impairment and the large number of persons to be screened, a household sampling based entirely on personal visits would have been prohibitively expensive. An alternative approach, and the one we followed, was to rely chiefly but not exclusively on telephone screening of households. Would such an approach introduce bias into the sample? In cities like Cleveland, more than three-fourths of all households have telephones. A special study which we made of 180 legally blind persons, drawn at random from the client list of the Cleveland Society for the Blind (the leading local private organization concerned with the welfare of the blind), showed that the proportion of blind persons with telephones was approximately the same as in the general population. In other words, a telephone sample was unlikely to discriminate against the blind. Moreover, a recent survey conducted by the California State Department of Public Health shows that considerable data on health can be obtained in telephone interviews and that with respect to validity, rate of return, and rate of completeness the telephone method is as reliable as mail questionnaires or personal interviews (3).

PROCEDURES

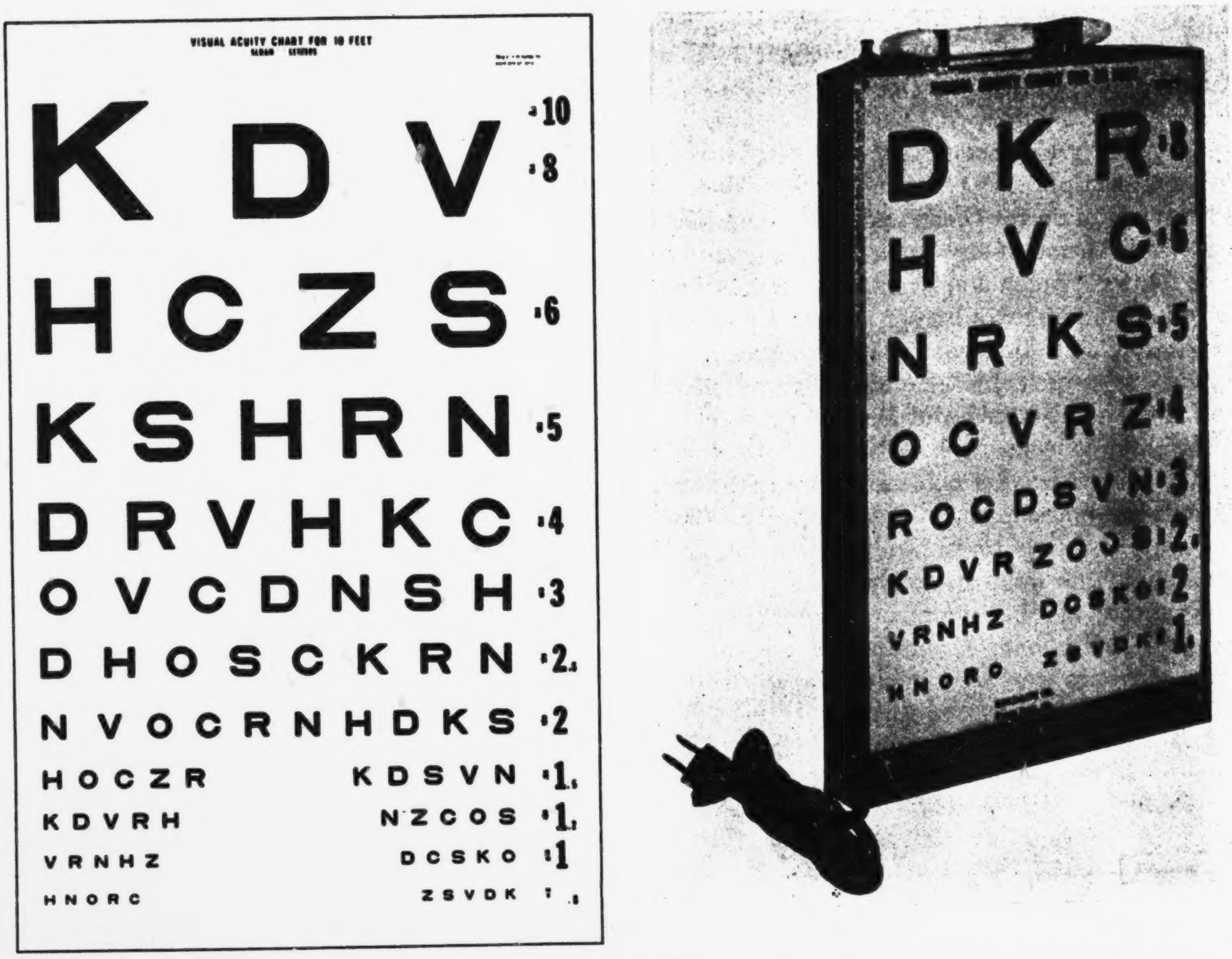
A random sample of 3689 households was drawn from the most recent Cleveland city directory. This total was divided into a telephone sample of 2778 homes and a nontelephone sample, including unlisted numbers, of 911 households. All telephone listings were assigned to interviewers for screening, but for economy we decided not to visit personally all nontelephone households in the sample; therefore, we drew a random subsample of approximately one-third, or 309, for screening purposes.

Screening questionnaires, identical in both samples, contained a checklist of health items adapted from the National Health Survey, including "serious trouble seeing even when wearing glass." Intensive face-to-face interviews were then conducted with persons reported in the two screenings, either by themselves or by other family members, as having "serious trouble seeing." These interviews provided measures of the severity of visual impairment, including subjective appraisals by respondents and tests of visual acuity.

To measure distance vision we used the Good-Lite Co. electrically illuminated 20-foot visual acuity chart with a 10-foot Sloan letter card (see figure) to allow for the probability that most households do not contain 20-foot living rooms (*A*). We standardized the distance at which this test was administered by equipping each chart with a 10-foot cord and instructing interviewers to extend the cord to full length between the subject and the chart. Respondents who were either illiterate or unfamiliar with the Roman alphabet were shown the so-called tumbled E vision chart. This chart has no letters but displays a figure resembling the letter E in various positions. Subjects are asked to tell the examiner the direction in which the figure prongs are pointing. Visual acuity measures obtained with this chart are comparable with those derived from lettered charts.

To record near vision we used the Lebensohn card (*B*) at 14 inches for both the Snellen and Jaeger tests. All tests measured best corrected vision; that is, subjects were asked to put on glasses if they used them. Interviewers were trained in the use of these devices by a local ophthalmologist.

Each respondent who said he had been examined within the past


VISUAL ACUITY CHART FOR 10 FEET
K D V 10
8
H C Z S 6
K S H R N 5
D R V H K C 4
O V C D N S H 3
D H O S C K R N 2.
N V O C R N H D K S 2
H O C Z R K D S V N 1.
K D V R H N Z C O S 1.
V R N H Z D C S K O 1
H N O R C Z S V D K
D K R 8
H V C 6
N R K S 5
O C V R Z 4
R O C D S V N 3
K D V R Z O
V R N H Z D O S K
H N O R

Sloan letter card used for testing visual acuity at 10 feet with Good-Lite Co. electrically illuminated 20-foot chart

3 years was asked to sign a release authorizing us to approach his physician for validating information. The few persons who had not been examined during this period were invited to have clinical examinations at our expense. These two sources provided data for checking results of our vision tests. Physicians were asked for measurements of distance and near visual acuity and field of vision, along with brief diagnostic information about the primary and secondary conditions leading to the impairment.

SCREENING RESULTS

Interviews were completed with 2014, or 73 percent, of the 2778 originally assigned telephone household listings. Unfortunately, we were forced to rely on an obsolete city directory, and as a result more than one-sixth of the 309 originally assigned nontelephone listings turned out to be vacant or demolished dwelling units. However, personal screening interviews were completed with 183, or 77 percent, of all existing nontelephone households assigned. A third of the nontelephone households contacted had obtained listed telephone numbers since the appearance of the original directory, and nearly one-fifth had unlisted numbers. In other words, only two-thirds of these households legitimately belonged in the nontelephone sample; that is, they either had no telephones or had unlisted numbers. The total of completed screenings was 2197 households containing 7192 persons.

We found, as have other researchers, that telephone screening costs only one-third as much as personal screening of households. The average cost of 2014 telephone screenings was $1.50; the average cost of 183 personal screenings was $4.50. The telephone method offers considerable economy. Does it also provide representative data?

Comparing characterists of individuals in the total sample (telephone and nontelephone) with census data for Cleveland, we find an identical distribution of age and an almost identical distribution of men and women (Table 1). Our sample had a slightly higher proportion of Negroes, but this difference may be because the census data were collected almost 3 years before our study was started and hence do not reflect the greater concentration of Negroes in the city since 1960. Also, we obtained information on race from households, and since census data were collected only for individuals in Cleveland, for comparison we projected household data for individuals in the sample. Comparing the racial

Table 1. Percent distribution of telephone and nontelephone sample characteristics, city of Cleveland

Characteristics	Total city population [1]	Samples [2]		
		Total N=7,192	Telephone N=6,499	Nontelephone N=693
Age:				
Under 65	90	90	89	94
Under 45	69	69	65	80
45–64	21	21	24	14
65 and over	10	10	11	6
65–74	7	7	8	3
75 and over	3	3	3	3
Sex:				
Men	49	48	48	49
Women	51	52	52	51
Race:				
White	71	68	71	56
Negro	29	31	26	44
Other	----------	----------	1	----------
Refused	----------	----------	2	----------
Family income:				
$0–$2,000	10	19	16	27
$2,000–$3,999	15	21	20	25
$4,000–$6,999	39	37	38	33
$7,000–$9,999	23	12	12	9
$10,000+	13	5	6	4
Refused	----------	6	8	2

[1] U.S. census.

[2] Actual numbers reporting varied somewhat from item to item. All reported numbers are unweighted. Percent distributions for the total sample are based on a weighting of nontelephone cases by a factor of 3 since we subsampled ⅓ of the assigned nontelephone households. This weighting restores the proper balance in the overall proportion of telephone and nontelephone households.

distribution for households, the sample characteristics were almost identical to the distribution reported by the census.

Our sample had proportionately more persons in the lower socioeconomic groups than reported by the census. While only one-fourth of Cleveland's families reported a total annual income of less than $4000 in 1960, our corresponding figure was two-fifths of the total sample of households in 1963.

In general, our telephone sample closely matched census figures. The greatest differences were between telephone and nontelephone households and also within the relatively small nontelephone sample itself. The nontelephone sample included more young people and disproportionately more Negroes than the telephone sample. Heads of households had less education and family income was lower in the nontelephone group.

Because the screening questionnaire included a checklist of chronic conditions and impairments adapted from the National Health Survey, the prevalence rates we obtained may be compared with reports from that study. In our total sample of 7192 persons (6499 telephone and 693 nontelephone) the prevalence of all reported cases of visual impairment (23.8 per 1000) was fairly close to the National Health Survey figure (19.8 per 1000). In our telephone sample the rate of reported impairments was even closer (19.3 per 1000) but the prevalence of visual impairment in our nontelephone sample (37.5 per 1000) was nearly twice that reported by the National Health Survey or by our telephone sample. What explains the appearently higher rate of visual impairment in the nontelephone group?

We have evidence that persons with severe visual impairment generally are low in socioeconomic status. Data from the National Health Survey indicate that the prevalence of severe visual impairment among families with an annual income under $2000 is nearly 9 times the rate among families with an income of $7,000 or more (4).

Apart from characteristics of the telephone and nontelephone populations, which may explain variation in the prevalence of visual impairment, there remains the question whether this variation can be attributed to the use of different interviewing techniques. Numerous studies show wide discrepancies between the number of diseases or conditions reported in household interviews and those found by medical examination. Also, the reliability of household interviews varies with the conditions being reported. For example, in a study by Trussell, Elinson, and Levin (5), diseases of the eye first reported in household interviews were relatively well matched with later clinical evaluations, while diseases of the respiratory system were poorly matched. On the other hand, relatively few of the eye-disease cases found by clinical evaluation were matched with conditions previously reported in family interviews.

A primary objective of our study was to determine whether telephone screening increases under-reporting of visual impairment. To check, we undertook a special reliability study and randomly selected for personal re-interviews a sample of 220 households (569 persons) which had not reported any cases of visual impairment in the original telephone screening. In all households we interviewed the original telephone respondent, and the questionnaire included the same health items that had been used in our first screening except that respondents were now questioned face-to-face. The re-interviews uncovered only one new case of visual impairment previously unreported. Further questioning about the duration and degree of impairment revealed that it was not severe; the person was reported as able, with correction, to read ordinary newspaper print.

Our reliability check thus suggested, at least for visual impairment, that the difference between prevalence rates in our telephone and nontelephone samples was not caused by variation in interviewing techniques. On the other hand, we found somewhat greater inconsistencies between the two sets of interviews with regard to other health conditions, which may be partly explained by the 1- to 3-month intervals between the original screenings and the follow-ups and also by the more unstable nature of some of the other conditions (Table 2).

Table 2. Health conditions of 569 people in telephone screening and personal re-interviews[1]

Condition	Agreed: Yes to both		Agreed: No to both		Disagreed: No on phone, yes in person		Disagreed: Yes on phone, no in person		Net change of disagreement	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Serious trouble seeing	0	-------	568	99.8	1	0.2	0	-------	+1	+0.2
Ever wear eyeglasses	243	42.7	288	50.6	18	3.2	20	3.5	−2	−.3
Arthritis, rheumatism	25	4.4	515	90.5	19	3.3	10	1.8	+9	+1.5
Heart, high blood pressure	25	4.4	532	93.5	9	1.6	3	.5	+6	+1.1
Varicose veins	12	2.1	540	94.9	11	1.9	6	1.1	+5	+.8
Repeated trouble with back or spine	6	1.1	548	96.3	8	1.4	7	1.2	+1	+.2
Diabetes	9	1.6	558	98.1	1	.2	1	.2	-------	-------
Deafness, serious trouble hearing	6	1.1	554	97.3	6	1.1	3	.5	+3	+.6
Wear hearing aid	3	.5	565	99.3	0	-------	1	.2	−1	−.2
Use cane regularly	2	.4	563	98.8	2	.4	2	.4	-------	-------

[1] Individuals for whom no "serious trouble seeing" was reported in the original telephone screening.

NOTE: Not all inconsistencies between the telephone and personal interviews can be attributed to inaccurate reporting alone as some recording errors may have been made. In addition, a period of 1 to 3 months occurred between the 2 interviews, thus raising the possibility of finding conditions in the personal interview which had not existed at the time of the original telephone screening.

In our study, as in a number of other epidemiologic surveys, evidence showed that respondents are more likely to report their own chronic conditions or impairments than those of other household members (6). However, we had no evidence that this tendency was related to the interviewing techniques, that is, telephone versus nontelephone.

VISION TESTS

As noted earlier, we originally planned to interview personally all individuals reported as having serious trouble seeing. Our two screenings (telephone and nontelephone) uncovered 152 such persons and 127, or 84 percent, were successfully interviewed during March and April 1963. Of these, 122 were actually given vision tests in their homes.

The various measures of visual impairment - our tests of near and distance acuity, answers to a series of questions about the trouble visually impaired respondents had in seeing, and reports from physicians - gave us an opportunity to correlate what people told us with actual tests of vision.

About 26 percent of the 127 visual impaired respondents interviewed replied negatively to the question: "Can you see well enough to read ordinary newspaper print with glasses?" This is the criterion by which the National Health Survey identifies the "severely visually impaired" population. It is worth noting that the Health Survey reports an almost identical proportion (28 percent) of all persons with visual impairments in this category.

However, since we administered our own tests of visual acuity, we have had a chance to compare the two sets of findings. Table 3 shows the relationship between reported ability of 122 persons to read ordinary newspaper print and their actual performance in reading the Jaeger near-vision card at 14 inches. Thirty-seven percent were unable to read 8-point standard newspaper print or smaller type on the near-vision test. Almost one-fourth of those who said they were able to read newspaper print could not read 8-point type. Conversely, approximately one-fifth of those who said that they were unable to read newspaper print could read 8-point or smaller type in the Jaeger test.

We do not offer these results as conclusive evidence of unreliability in the National Health Survey criterion for defining severe impairment, especially as we tested near vision at 14 inches and since distance or size of type was not specified in the Health Survey question regarding ability to read newspaper print. Further more, we did not learn whether persons claiming ability to read newspaper print, but unable to read 8-point type on the Jaeger test, could in fact do so for a sustained period of time. Nevertheless, this correlation of verbal reports and test results suggests that any measure of visual impairment based entirely on what people report is subject to error.

Verbal reports, of course, are hardly adequate to identify all blind persons, particularly those who have more than light perception, which is usually defined as the ability to see light but not

Table 3. Association between reported ability to read ordinary newspaper print and performance in Jaeger near-vision test [1]

Visual acuity level	Reported ability to read ordinary newspaper print with glasses (percent)		
	Total (N=122)[2]	Able to read (N=87)[2]	Unable to read (N=35)[2]
Totally blind	2	----------	10
Light perception	4	----------	14
Less than 20/170	5	----------	22
20/170	5	5	5
20/130	4	3	7
20/100	5	6	5
20/80	5	3	9
20/70	3	1	7
20/65	4	5	----------
20/50 [3]	17	19	9
20/40	5	6	5
20/30	20	24	7
20/25	17	23	----------
20/20	4	5	----------
Total	100	100	100

[1] Tested at 14 inches.

[2] Actual number. In computing percentages, the number of visually impaired persons from the nontelephone sample has been weighted by a factor of 3.

[3] Level of acuity needed to read newspaper text.

its source. Consequently, to distinguish the blind we replied on our test of visual acuity. All respondents who scored 20/200 or less on the 10-foot Sloan letter chart were considered to be blind. We found that 10 percent of the reported cases of visual impairment fell into this category, a figure which could have been expected from the proportion of estimated blindness (2 per 1000 population) in the total universe of visual impairment as defined by the National Health Survey (19.8 per 1000 population).

We attempted to check results of the vision tests against reports from physicians. Eighty-four persons (79 percent) who said they had been examined within the past 3 years signed releases authorizing us to obtain information about them from their physicians. Medical reports were obtained on 55 persons, or nearly two-thirds of the ones who had signed. In addition, clinical examinations were arranged for nearly half (14) of the respondents who had not been examined within the previous 3 years. As a result, we obtained clinical data consisting of distance and near-vision acuity and brief diagnostic information on 69, or 54 percent, of the visually impaired respondents.

The two sets of observations for the 69 clinically validated cases varied considerably (Table 4). According to the physicians, 48 percent of the group had 20/25 vision or better; in contrast

Table 4. Percent distribution of visual acuity scores

Visual acuity level	Clinically validated		Not clinically validated, tested at home (N=53)[1]	All respondents, tested at home (N=122)[1]
	Clinical reports (N=69)[1]	Tested at home (N=69)[1]		
20/16-20/25	48	29	38	34
20/30	13	18	10	14
20/40	16	13	21	15
20/50	8	4	8	6
20/60	----------	12	3	7
20/70-20/80	3	7	1	5
20/100	----------	5	8	6
20/120	----------	1	1	1
20/160	----------	2	2	1
20/200 but more than light perception	9	1	1	1
Light perception	2	6	4	6
Totally blind	1	2	4	3
Total	100	100	100	100

[1] Actual number. In computing percentages, the number of visually impaired persons from the nontelephone sample has been weighted by a factor of 3.

only 29 percent were so scored by our interviewers. At the other end of the scale, clinical reports indicated that only 3 percent had light perception or were totally blind; according to our vision tests, the figure was 8 percent.

Identical test results were obtained in only 22 percent of the cases. Furthermore, in most instances of disagreement, the interviewers recorded less distance vision; that is, more visual impairment than the physicians. For the 53 persons without clinical validations, our data suggest that the distribution of visual acuity scores was not significantly different from the clinically validated.

What explains the discrepancies between clinical and home examinations? It must be observed that our tests were not intended as substitutes for clinical examinations. Thus for comparison with clinical reports, the results of our 10-foot distance tests were converted into standard 20-foot measurements by multiplying them by two. For closer approximation of 20-foot testing with the apparatus we used, however, one should place a pair of 0.25 lenses over the patient's eyes or eyeglasses during the visual acuity test. This we were unable to do in our study.

Although reporting physicians suggested that many patients underestimated the elapsed time since their most recent visit, there is no evidence from our study that the inconsistency between our distance tests and what physicians reported was caused by the time lag between their examinations and our tests. Indeed, a surprisingly large proportion of our respondents had been examined within a few months before our two contacts with them and some of them afterward.

There is reason to believe, however, that physicians differ in their vision-testing procedures, not only as compared with our household examinations but among themselves as well. Wide variation among physicians in arriving at a diagnosis, along with errors and inconsistencies in diagnoses, have been reported elsewhere (7). In our study there was so little uniformity among physicians in the distance at which they conducted near-vision tests and in reporting that we were unable to compare their findings with our near-vision tests. While there was greater uniformity in physicians' procedures for testing and reporting distance vision, we can make no definitive statement about the reliability of our vision-testing procedures or the physicians' reports. However, we feel that our fairly simple vision tests achieved at least one objective - a check against self-reported disability.

CONCLUSIONS

Any vision impairment study using the telephone for screening must be supplemented by a sample of nontelephone households, in view of important demographic differences between telephone and nontelephone populations and the possibility that such differences may be associated with the prevalence of the condition. The proportion of interviews completed with assigned listings would be much higher than in our study if up-to-date directories were available.

As for the reliability of the telephone strategy in collecting impairment data, we conclude that our approach is as dependable as personal interviews for screening to determine crude rates of visual impairment and other chronic conditions. Telephone screening is economical, costing about one-third as much as personal interviews. Vision tests can be given in homes by nonmedical investigators. Such tests offer a useful check against self-reporting of visual impairment. However, more research is needed on the general reliability of vision testing (medical and nonmedical), particularly at the lower ranges of visual acuity. In view of suspected differences in testing procedures, what needs to be explored, it seems to me, is variation not only in different testing devices (8) but among different observers using the same device.

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